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Effect of Nitrate of Soda on Development of the Halehaven Peach

By
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Bulletin 493

UNIVERSITY OF ILLINOIS
AGRICULTURAL EXPERIMENT STATION

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Effect of Nitrate of Soda on Development of the Halehaven Peach

By RICHARD V. LOTT, Associate Chief in Pomology

KNOWLEDGE of the changes which the fruit undergoes during its development is essential to the devising of the most desirable orchard practices. Altho there are numerous publications dealing with fruit-bud differentiation, fruit setting, fruit drops, the effect of soil-management methods upon the quantity and grade of the resulting crop, changes occurring in storage, and similar problems, relatively little study has been given to the physical and chemical changes which occur in the fruit during its development from the blossom to the ripe fruit.

The work here reported was conducted in the peach orchard of the Department of Horticulture at Urbana, Illinois, in 1938, with the object of obtaining some information on the physical and chemical changes which occur in the development of the peach fruit from the blossom to the soft ripe stage of the flesh, and the effect of a differential supply of available nitrogen upon them. In addition to this, some study was made of the morphological changes in the fruit thruout the season.

REVIEW OF LITERATURE

The principal contributions to the existing knowledge of the development of the fruit of the peach follow.

Physical Changes During Fruit Development

Strasburger,^{61*} referring to stone fruits, said:

" . . . they can be readily used for studies in the development of the various tissues, especially of the endocarp in the process of 'stoning' which takes place at a definite period of their growth, during which, for some little while, the young fruit does not increase in size."

Likewise, Sorauer^{60*} observed in 1895, "In the case of stone fruits . . . during the period in which the stone is formed the fruit does not increase much in size."

Thus some conception of periodicity of size increase in stone fruits existed long before the first of the modern investigations on the subject. It is to relatively recent studies, however, that we must give credit for our present knowledge of the subject.

*These numbers refer to literature citations on pages 381 to 384.

The first comprehensive attempt to determine the seasonal trend of development in the peach fruit was that of Connors,^{13*} who, in 1918, measured at weekly intervals the suture diameter of the fruits of nine varieties ranging from early to late in season of ripening. Measurements were started one week before the stones began to harden and were continued until harvest. The following year he determined the increase in suture diameter in Greensboro, Belle, and Elberta varieties, beginning before petal fall and continuing to 61 days after bloom. His conclusions are given below in some detail because they have been substantiated in the main by several other investigators and form the historical basis for any discussion on peach fruit development.

"The growth of the fruit of peaches is quite definitely divided into three stages. . . . Stage 1: Rapid development of the fruit apparently due mainly to increase in size of the seed part. Up to the 44th day from the beginning of measurements. Stage 2: Rest period during which the seed is formed and the stones become hard. Stage 3: Period of rapid growth of flesh to maturity, beginning four to five weeks before ripening time.

"The stage subject to the greatest modification is Stage 2. This may be only one or two weeks, in the case of the early clingstone varieties, or it may be 4 to 7 weeks in the case of the later ripening varieties."

The term "seed," as Connors used it, apparently included stone and kernel. He also pointed out that Mayflower, Early Wheeler, and Greensboro were typical of varieties ripening before Carman in that they did not produce full-sized cotyledons. This phenomenon has since received considerable attention in discussions of peach fruit development.

Blake^{5*} studied size increase in Elberta from blossom bud to maturity during the season of 1925. His data substantiated the theory of three growth periods described by Connors. He also found that the polar diameter increased more rapidly than the suture and cheek

Note. In this Bulletin the following terminology is used:

FLESH—the pulpy part of the fruit outside the stone; botanically the fleshy pericarp.

STONE—the inner portion of the fruit that becomes hard and stonelike; botanically the endocarp.

KERNEL—the integuments and their contents; the ovule or seed.

POLAR DIAMETER—the greatest distance from base to apex of the fruit.

SUTURE DIAMETER—the greatest distance between ventral and dorsal sutures.

CHEEK DIAMETER—the greatest distance thru the fruit at right angles to the suture diameter.

GROWTH PERIOD—a relatively definite interval during the time the fruit is increasing in size. These growth periods will be referred to as the first growth period, second growth period, and third growth period; or simply as the first, second, or third period.

FINAL SWELL—the rapid increase in the size of the fruit in the last few weeks before harvest, coincident with the third growth period.

C TREE, FRUIT, LEAF, etc.—the tree (or its parts) that received no fertilizer.

N TREE, FRUIT, LEAF, etc.—the tree (or its parts) that received fertilizer.

diameters during the first 51 days, then the suture diameter increase was the most rapid of the three, and during the final growth period both the suture and cheek diameters increased more rapidly than the polar diameter.

In 1926 Dorsey and McMunn^{18*} made the first study of the developmental relationships of the different parts of the fruit, using Elberta. They also found that the fruit increased in length in three periods similar to those described by Connors. During the first period the stone and kernel reached nearly maximum length. The endosperm made its most rapid growth in the second period. The cotyledons began rapid growth about the 60th day after bloom and reached full length in less than a month, about two weeks before flesh maturity. The beginning of the second growth period coincided with the initiation of hardening in the stone, the attainment of approximately maximum length by the kernel, and the start of rapid growth in the endosperm.

Blake *et al*^{6*} reported polar, suture, and cheek diameter measurements for the seasons 1929 and 1930 on Elberta fruits from high-carbohydrate and from high-nitrogen trees. The fruits in both seasons showed the usual three periods of size increase. The high-nitrogen fruits had a longer third period, resulting in several days later ripening.

That all peach varieties may not have periodic growth is shown by the data of Lilleland^{37*} on the seasonal increases in cheek diameter in seven varieties. He found periodicity in Elberta, Lovell, St. John, Levi, and Late Champion but not in Sneed and Triumph. He thought that time of maturity was not definitely responsible for the occurrence of periodicity, since St. John, an early variety, exhibited distinct periodicity. Tukey^{67*} reported a second period of nine days' duration in Triumph in New York. This discrepancy with Lilleland's results may be due to the method of measurement since Tukey based growth on polar diameter increase whereas Lilleland used suture diameter increase. As reported by Blake,^{5*} the peach fruit increased more rapidly in polar diameter early in the season than later, but suture diameter increased more rapidly after the rate of polar diameter increase had begun to slow down. Volume measurements would have to be used to determine definitely whether the Triumph variety had periodicity of size increase.

In 1932 the writer^{39*} studied the development of Hiley from the beginning of stone hardening until flesh maturity. To the usual diameter measurements were added volume, green-weight, and dry-weight determinations. While a second growth period was evident from the diameter, green weight, and volume data, it was not nearly so clearly defined as has been reported for other varieties. When dry weight was used as the measure of growth there was only a suggestion

of a second period. The dry weight of the stone increased most rapidly during the second period and reached a maximum at its end. Likewise, the kernel was increasing steadily in dry weight at this time and made its most rapid increase near the end of the period. Similar results were obtained in 1933 with Hiley and Elberta and in 1934 with Elberta. When growth was measured on the basis of dry-matter increase there was no definite second growth period. If such a period had been present it would have been confined to the flesh since the stone and kernel were both increasing rapidly in dry matter.

The next investigation on this subject was that of Tukey.^{67*} In 1933 he measured the length increases of the fruit, stone, and kernel of five varieties with intervals of 91 to 144 days from bloom to harvest. In each variety he found the usual three periods of size increase and also reported the following results: (1) The duration of the first period was similar in all varieties. (2) the duration of the second period was directly correlated with the date of ripening, being shortest in the earliest variety and longest in the latest ripening sort. This is in agreement with Connors.^{13*} (3) Initiation of stone hardening was almost simultaneous for all five varieties, but hardening was most rapid in those ripening earliest. (4) Nucellus and integuments in all varieties reached maximum size near the end of the first growth period. (5) The embryo development in all varieties was similar, rapid enlargement beginning at approximately the end of the first period and maximum size being reached in 29 to 31 days.

Chemical Changes During Fruit Development

The first comprehensive study of the changes which the chemical constituents of the peach fruit undergo during its development was made by Bigelow and Gore^{4*} in 1905. They analyzed six varieties, ranging in season of ripening from early to late, at three stages which they designated as June drop, stone just hardened, and market ripe (probably what is now known as hard ripe). Three of the varieties were also analyzed at the full-ripe stage. Their publication includes an excellent synopsis of the analytical work on peaches which had been done up to that time. Since none of these former analyses were extensive, knowledge of the chemistry of the peach really started with their work. A notable feature of their report was the need they pointed out for expressing results in amounts as well as on a percentage basis, a fact since overlooked by some investigators.

The data of Bigelow and Gore show large increases in the solids of the peach fruit from one sampling date to the next, a marked increase in percent of solids in the stone and kernel, but a decrease in the percent in the flesh in the last sample. The sucrose content of the flesh was very low in comparison with reducing sugars in the first sample but two to three times as great in the last sample. The amounts

of nitrogen and ash increased as the season progressed. The only determination made on stone and kernel was made for solids content. The only carbohydrates determined were sugars. The major fault of their work, one which they recognized and mentioned, was that samples were not taken more frequently.

In 1905 Van Slyke *et al*^{73*} published extensive analyses of the parts of fruit trees. They found the following relative amounts of nutrients in peach fruits, based on the average of the three varieties, Elberta, Champion, and Hills Chili, at maturity: nitrogen 1.00, phosphoric acid (P_2O_5) .49, potash (K_2O) 2.05, lime (CaO) .12, and magnesia (MgO) .23. Based on percentages, their data show two to three times as much potash as nitrogen in the flesh, considerably less phosphoric acid, more nitrogen in the stones than in the flesh, and two to four times as much nitrogen as phosphorus or potassium in the stones.

Thompson and Whittier,^{63*} in a significant but seldom mentioned study in 1912, pointed out the desirability of determining the relative proportions of dextrose and levulose in fruits. They found that in the juice of both green and ripe Belle peaches the percent of levulose and dextrose was approximately equal. In the green fruit, however, the percent of reducing sugars (levulose and dextrose) was more than eight times that of sucrose, while in the ripe fruit the percent of sucrose was over twice that of the reducing sugars. In 1913 the same authors^{64*} published the results of a study in which the juice of peaches was analyzed at intervals starting one month before the stone hardened and continuing to flesh maturity. They found that levulose and dextrose occurred in approximately equal quantities but in no case did the dextrose exceed the levulose. The percent of these two sugars decreased uniformly toward maturity, accompanied by a corresponding increase in sucrose.

The next contribution to the knowledge of chemical changes during development in the peach was that of Appleman and Conrad.^{3*} They studied the pectin changes in Crawford peaches from the hard ripe to the soft ripe stage. They concluded:

"The amount of soluble pectin formed from the insoluble protopectin in the cell walls so closely paralleled the degree of softening of the peaches during ripening that this transformation may be considered the chief process responsible for the softening of the fruit. Other processes besides this pectic change are probably involved in the extreme softening of overripe peaches."

Kokin^{35*} studied the sugar changes in the flesh of Elberta and Champion during the last 84 days of the season of 1928. His data for both varieties show the usual low percentages of sucrose early in the season and an increase to maturity. In Elberta there was more glucose than fructose up to the last three weeks, then there was a drop in glucose but a continued increase in fructose, so that the percent of fructose was nearly 50 percent greater at harvest. At that time fructose

constituted nearly 20 percent of the total sugar. In Champion, glucose exceeded fructose in the first two samples only, then decreased rapidly and was entirely absent during the last month. Fructose continued to increase and made up nearly one-third of the total sugars at maturity. These results are not in agreement with those of Thompson and Whittier cited above. The lack of agreement may be due entirely to difference in the varieties studied and thus shows the danger of drawing widespread conclusions from the results of study of a single variety.

In 1930 Nightingale *et al*^{51*} published the results of a study of the comparative chemical composition of the flesh of Elberta fruits from high-carbohydrate and high-nitrogen trees. Only the last seven weeks of the season were included. The outstanding results were a higher percentage of sugars, soluble pectin, protopectin, cellulose, and dry matter at maturity in the flesh of the high-carbohydrate fruits, and higher percentages of nitrogen and ash in the flesh of the high-nitrogen fruits.

In an investigation of the development of Hiley from stone hardening to flesh maturity, conducted by the writer^{39*} in 1932, the analysis of stone and kernel was included in the study of chemical changes occurring during development. By expressing results on the basis of amounts as well as in percentages, a more comprehensive picture of the seasonal trend of the constituents was obtained. The most significant feature of the flesh-stone relationship was the rapid accumulation of hemicellulose in the stone, while all carbohydrates in the flesh were increasing slowly and the sugars in the stone were decreasing. This relationship, coupled with the fact that the period of greatest accumulation of sugars in the flesh (the final swell) coincided with a decrease in all carbohydrates in the stone, indicated that the stone was the dominant part of the fruit until it reached its maximum carbohydrate concentration, which was also its point of maximum dry weight. The decrease in dry weight and in all determined materials in the stone during the final swell of the flesh showed that the stone reached physiological maturity before the flesh. The kernel increased rapidly in ether extract during the third growth period of the flesh after the embryo had attained its greatest size. The amount of ether extract in the kernel at maturity was more than twice that of all of its other determined constituents. Further study^{40*} with Hiley and Elberta in 1933 and with Elberta in 1934 confirmed these results.

In 1935 Lott and Ashley^{41*} compared the development of five varieties varying from early to late in season of maturity. The size, fresh and dry weights, and composition of each variety when ripe were compared with these characteristics in the late-ripening Elberta on the same date. It was found in the early varieties that the stone continued to increase in dry weight until harvest, instead of reaching a maximum

in the second period or early in the third period, as Elberta did. This competition for materials between the flesh and the stone in the third growth period was associated with small fruit size and low sugar content in the flesh at maturity. The percent of sugar in the flesh increased directly with the date of ripening. The Elberta kernels increased much more rapidly in dry weight, nitrogen, and ether extract than the earlier varieties. The amount of each of these was greater in the Elberta kernels on the ripening date of any earlier variety than in the kernels of the earlier variety. This work showed the impossibility of applying directly to any variety the information obtained from another variety having a different season of maturity. It is also quite possible that varieties having the same season of ripening differ enough in their development to make the study of individual varieties desirable.

The literature which has been reviewed above shows that since the work of Connors^{13*} the conclusion has been reached by nearly all investigators of the subject, that the fruits of the peach have three fairly distinct periods of size increase. When the present problem was initiated, no one had followed both the physical and the chemical changes in the fruit or its separate parts from bloom to flesh maturity. This investigation was undertaken in order to supply some of this needed information.

EXPERIMENTAL MATERIALS AND METHODS

Materials

For use in this investigation two adjacent six-year-old Halehaven trees were selected. They were apparently of the same size and vigor and had made a vigorous growth in 1937, the length of the longer terminal shoots ranging from 10 to 18 inches. There was an abundant crop of fruit buds, and approximately 50 percent of the nodes on the longer shoots had two buds. Only an occasional bud failed to survive the winter of 1937-38.

The soil is a brown silt loam underlain with clay loam at a depth of 8 to 10 inches. The slope of approximately 3 percent is toward the southwest and away from the trees used. A cover crop of rye, sowed in the fall of 1937, was allowed to head and was then disked into the soil on June 3. This was followed by a crop of natural vegetation, which was mowed August 1. The vegetation under the trees was mowed with a scythe as frequently as was necessary to keep it down to a height of a few inches.

To determine the effect of the available-nitrogen supply upon fruit development, a difference in vigor between the two trees was established by making two applications of nitrate of soda to one of them.

The applications, of 5 pounds each, were made March 28, 17 days before full bloom, and June 4, when the stone was beginning to harden, 51 days after bloom. The fertilizer was scattered uniformly over the surface of the ground under the tree, extending from the trunk to the tips of the branches. Rain fell in the night following each application, so the material undoubtedly went into solution within 10 to 12 hours after application.

The daily mean temperature and the precipitation are shown in Fig. 1. The mean temperature for March was 3.2 degrees above normal, with the result that the buds developed somewhat more rapidly than in most seasons. A cooler period started April 1, with the following minimum Fahrenheit temperatures: April 1, 33°; 2, 30°; 3, 26°; 4, 30°; 5, 31°; 6, 33°; 7, 30°; 8, 34°; 9, 30°; 10, 32°. The buds developed very slowly during this period. Rain which fell on April 8 froze on

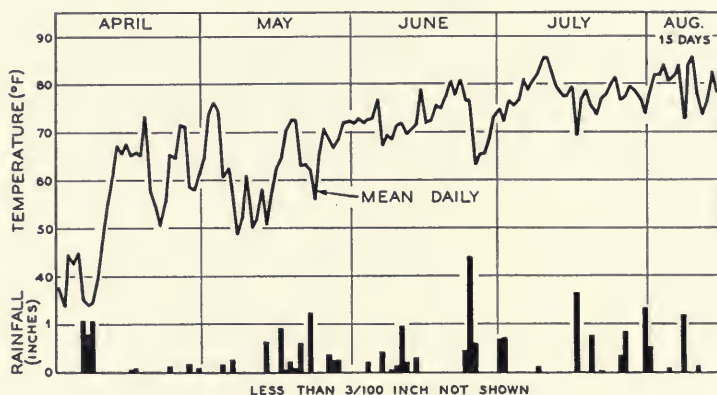


FIG. 1.—DAILY TEMPERATURES AND RAINFALL AT URBANA DURING GROWING SEASON, 1938

the trees, resulting in a coating of ice approximately $\frac{1}{4}$ inch thick on all parts of the tree. This remained on the trees for nearly 24 hours, and melted on the 9th, which was clear and warmer. The petals were well colored and the buds almost ready to open, but no buds were killed by the ice and accompanying cold. Clear and increasingly warmer weather followed. The trees had a few open blossoms on April 13, were about one-half in bloom on the following morning, and were in full bloom by midafternoon. Only a few buds opened after this date. The weather of April 13 and 14 and for several days thereafter was warm and sunny, with abundant bee activity and favorable conditions for growth following pollination. Consequently April 14 is considered the date of full bloom and all data are referred to that as a base date.

There was no evidence of a deficiency of moisture at any time during the season. The most extended period of light rainfall extended from April 9 to May 7. Apparently there was an adequate moisture supply during this period, since there was no evidence of wilting of the peach leaves nor of nearby vegetation.

Methods

Sampling. In all collections the samples were taken from the two trees within 30 minutes, and were then taken to the laboratory about five minutes distant for preparation. All samples were collected in the early morning, not later than 8:30 a.m. during the first few weeks after bloom and before 7:30 a.m. thereafter.

Fruit samples. Samples were collected at intervals of approximately one week from full bloom to the soft ripe stage of the flesh, taking care to include fruits from all portions of the tree. The first sample was taken on April 14, when a sample of 300 flowers was collected from each tree. The pistil was removed by separating the base of the ovary from the calyx cup with a sharp scalpel. Thereafter 200 to 300 fruits were included in each sample until May 12 and the whole sample preserved for analysis. Beginning with that date a sample of 75 to 100 fruits was picked from each tree. The fruits were taken to the laboratory, weighed individually, and grouped into classes of 2-gram intervals until July 21 and in classes of 5-gram intervals thereafter. Since the objective was to measure the mean condition on the tree, the smallest class and the largest class was discarded and a 25-fruit sample selected from the remaining classes, the number of fruits taken from each class being proportional to the total population of that class.

The selected sample was weighed to obtain the fresh weight per fruit; the polar, suture, and cheek diameters were measured with a caliper; and the volume determined by displacement in water in a graduated cylinder. Because of the small size of the fruit, no separation into its component parts was attempted before May 12. Beginning with the May 12 sample (28 days after bloom) the kernel was removed. The stone was first hard enough to separate from the flesh on June 10 (57 days after bloom), and thereafter the fruit was separated into the three parts: flesh, stone, and kernel.

After the weight, diameters, and volume of the fruit were determined, the flesh was removed from the stone and placed at once in a ventilated electric oven at 90° C. and left for 30 minutes, after which it was transferred to a similar oven kept at 65° C. and left until a constant dry weight was reached. The stones with the included kernels were weighed, measured, their volume determined, separated from the kernel by cracking, and the weight, diameter, and volume of the kernels obtained. After securing the above data, stones and kernels

were dried in the same manner as the flesh. The weight and volume of the flesh were determined as the differences between the weights and volumes of the fruit and those of the uncracked stone. Likewise, the weight and volume of the stone were calculated as the differences between those of the uncracked stone and the kernel.

Preparation. The first four fruit samples were ground by hand in a mortar, on account of the small size of the dry sample. They were reduced to pass a 60-mesh sieve. Finer grinding was impractical because of the great amount of epidermal hairs present. In all later samples the flesh (including the stone until it was hard enough to separate) was ground in a Wiley mill to a particle diameter to one-half millimeter. Further grinding was impossible because of the hygroscopic nature of the material, especially as maturity was approached. These samples were further reduced before analysis, as explained later.

The stones were cracked in a burr mill into pieces 1 to 3 millimeters wide and then ground in a ball mill to pass a 100-mesh sieve. The kernel samples were all ground by hand in a mortar, since the samples were relatively small. After ether extraction, they were again ground to homogenize the extracted residue before further determinations were made.

The ground samples were stored in the dark in tightly stoppered sample bottles until analyzed. Duplicate samples were used for all determinations.

Dry matter. This was obtained by drying, as previously explained. The dried samples were weighed and the percent of dry matter calculated on the basis of the original fresh weight.

Ash. A one-gram sample of the dry powder was ignited to a white ash in a porcelain crucible over a Bunsen flame.^{38*}

Ether extract. Two-gram samples of the dry ground kernels were extracted for 20 hours with anhydrous ethyl ether in a standard continuous extraction apparatus. The kernels were the only samples upon which this determination was made, since previous experiences had shown that the flesh and stone did not contain measurable quantities of the substances extractable by ether.

Nitrogen. Only total nitrogen was determined. The Kjeldahl method modified to include nitrates, as described by Loomis and Shull,^{38*} was used on 1-gram samples.

Sugars. *Extraction.* After considerable preliminary investigation, the following method of extraction was found to be most satisfactory under the prevailing conditions for the flesh and kernel but was not necessary for the stone samples.

A 2-gram sample of the dry material was ground in a porcelain mortar with a minimum of water until it was a finely reduced homogeneous mass. The ground sample was washed onto filter paper in a 4-inch Buchner funnel and the filtrate carried thru with slight to moderate suction. The colloidal material in the peach flesh and kernels made suction necessary. The sample was washed ten times with small quantities of water. Tests showed that this removed all of the sugars.

The stone samples were extracted by placing 2-gram samples on filter paper in 75-mm. glass funnels and washing ten times with small quantities of water. These samples could be washed fairly rapidly by this method.

Determination of reducing sugars. In all cases the extracted solution was cleared with 1 cc. of a saturated solution of neutral lead acetate, filtered, thoroly washed, delead with a saturated solution of potassium oxalate, filtered, and made to volume. Duplicate aliquots of the filtrate were taken for the determination of reducing power. Reduction was carried out according to the Munson-Walker conditions^{44*} and the amount of reduced copper determined by the Shaffer-Hartman method.^{58*} All carbohydrates were calculated and expressed as dextrose.

Determination of total sugars. A 50-cc. aliquot of the cleared and delead sugar solution was pipetted into a 100-cc. volumetric flask, and 25 cc. of water and 5 cc. of concentrated HCl added. The flasks were placed immediately in a water bath at 70° C. and left in the bath for five minutes after the contents reached a temperature of 67° C. The flasks were then removed, cooled at once, nearly neutralized, and duplicate 50-cc. aliquots taken for the determination of reducing power.

Sucrose. The reducing power obtained in the total sugar determination minus that of the reducing sugar determination was considered to be sucrose.

Starch and dextrin. These were determined on the residue from the sugar extraction, following the general procedure outlined by Loomis and Shull,^{38*} using fresh saliva and completing hydrolysis by refluxing in 2½ percent HCl for 2 hours. Reducing power was determined as for sugars.

Hemicellulose. While this should more correctly be designated as water-insoluble acid-hydrolyzable materials, the more convenient term "hemicellulose" will be used.

The residue from the starch-dextrin extraction was refluxed for 2 hours in 2½ percent HCl, filtered, washed, cooled, nearly neutralized, cleared and delead, made to volume and duplicate aliquots taken for the determination of reducing power.

CHANGES DURING FRUIT DEVELOPMENT

Morphological Changes

A summarized description of the gross morphological changes which occurred during the season in the fruit is given in Table 1. A similar summary is given in Table 2 for shoot and leaf growth. This material is included at this point in order to provide a background for the detailed discussions on the growth and chemical changes in the fruit. Certain morphological aspects of fruit development which could not easily be included in Table 1 will be considered at this time.

At full bloom the two ovules were the same size, with the exception of an occasional ovary in which one ovule was slightly smaller. Seven days later one ovule was noticeably thicker than the other and slightly

TABLE 1.—SEASONAL DEVELOPMENT OF FRUIT OF TWO PEACH TREES AT URBANA, ILLINOIS, 1938

Date	Days after bloom	Condition
Apr. 14	0	Full bloom.
18	4	Half of petals fallen.
21	7	All petals fallen, stamens erect, anthers dry, tip $\frac{1}{2}$ inch of style dry.
22	8	Shuck abscission zone evident in 25 percent of N fruits, none in C fruits.
25	11	Shuck abscission zone evident in 50 percent of fruits, stamens dry.
27	13	Shucks abscised in all fruits, shuck withered—more advanced in N fruits—tip one-third to one-half of style dry.
28	14	Shucks brown, withered.
May 5	21	Shucks all off; styles mostly abscised, more from N than from C fruits.
June 2	49	Stone beginning to harden at tip, down ventral suture, and inner epidermis.
6	53	Endosperm first evident macroscopically. Nucellus and integument near maximum size.
June 10	57	Stone first hard enough to separate from flesh, still somewhat soft at base and next to flesh at tip. Embryo first evident macroscopically.
29	76	Endosperm full length of nucellus in most cases, embryo half as long.
July 7	84	Stone at maximum hardness as measured by resistance to cutting. Embryo $\frac{3}{4}$ length of nucellus, endosperm a thin layer. Integument started to color—cream with slightly darker tip. Third period of flesh development started.
15	92	Embryo filling integuments except for very thin layer of endosperm.
21	98	Blush present on some C fruits, none on N. Integument dark cream, slightly darker at tip.
29	106	Ground color of C fruits yellow-green, 50 percent overlaid with red. Flesh lemon-yellow with some red in it and red at stone. Ground color of N fruits still quite green, with 10 percent overlying red. Integument same color as on July 21.
Aug. 4	112	Ground color of C fruits yellow, 90 to 100 percent overlaid with crimson. Considerable red in flesh and adjacent to stone. Ground color green in N fruits, 50 percent overlaid with crimson, less red in flesh than C.
9	117	C fruits soft ripe, ground color orange-yellow overlaid with deep crimson on exposed side, with streaks and splashes of carmine and crimson on shaded side, very little ground color showing. Flesh orange-yellow, with red conspicuous along main vascular bundles and at stone. Integument mostly dark cream, some with light brown chalaza, a few entirely light brown.
15	123	N fruits soft ripe, same general appearance as C fruits on Aug. 9, not as highly colored but as attractive, less red in flesh. Half of integuments light brown, others dark cream or dark cream with light brown chalaza.

C = check tree. N = tree treated with nitrate of soda.

longer; the smaller ovule was twice as long as it was at bloom, but it was the same width as at bloom and slightly thinner. One month after bloom the suppressed ovule was still white in color and four times as long and twice as wide as at bloom but only about half as thick. Whether this difference in size was due to continued growth or to the flattening of the suppressed ovule against the stone by the growth of the other ovule was not determined. This information indicates the possibility of being misled concerning the growth of the suppressed ovule because of the more rapid development of the normal ovule after bloom. Harrold^{32*} stated that the two ovules in Carman developed equally until about three days after bloom, when one

TABLE 2.—SEASONAL DEVELOPMENT OF SHOOTS AND LEAVES OF TWO PEACH TREES AT URBANA, ILLINOIS, 1938

Date	Days after bloom	Condition
Apr. 14	0	Rosette of leaves up to $\frac{1}{2}$ inch long in C, up to 1 inch in N.
May 5	21	N leaves darker and larger than C leaves from here to end of season.
12	28	C shoots up to 3 inches long; N shoots up to 4 inches long.
June 8	55	C shoots up to 5 inches long, approximately 90 percent ceased elongating. N shoots up to 8 inches long, large percentage still elongating, those under 3 inches ceased elongating.
22	69	C shoots all ceased elongating. N shoots up to 4 inches long ceased elongating, others decreasing in rate of elongation.
July 1	78	N shoots above 6 inches long still elongating. Some of longest with lateral secondary shoots.
14	91	N shoots above 10 inches long still elongating.
21	98	N shoots above 10 inches long still elongating slowly.
29	106	N shoots all had ceased elongating.
Aug. 10	118	C leaves had decreased in dry weight compared with July 1 (start of third growth period). N leaves were still increasing in dry weight as compared with July 1.

stopped. Ragland^{57*} reported that one ovule was often smaller than the other in Phillips Cling at full bloom, and that this difference prevailed for 10 or 12 days, when the smaller one aborted. This discrepancy with the present work may be due to the varietal or the environmental difference or both.

The arrangement of the bundles in the pedicel was essentially that described by Bonne.^{7*} From the vascular cylinder at the base of the fruit there were 10 to 12 bundles that entered the stone and branched from it into the flesh at various levels. In addition to these bundles the stone also contained the bundles that extended from the vascular cylinder at the base of the fruit to the ovules, one to each ovule. These are the bundles that Ragland^{56*} called funicular bundles. The major bundles exterior to the stone were the two large ventral bundles lying in deep grooves, one on each side of the ventral suture of the stone, and the dorsal bundle lying in a groove along the dorsal suture. The

ventral and dorsal bundles diverged from the stone just back of its tip and continued into the style. There were a few small bundles passing directly from the vascular cylinder into the flesh, but the main vascular system of the flesh developed by the branching of the bundles entering it from the stone and from the dorsal and ventral bundles.

In the young peach fruit at full bloom the principal vascular bundles extended the full length of the fruit and continued on into the style. Sixteen days after bloom it was apparent that the interior cells of the vascular bundles in the tip one-fourth of the fruit had broken down and disintegrated to form ducts which rapidly became more prominent. They were easily distinguished by a low-power microscope 22 days after bloom. Thereafter they gradually appeared thruout the flesh but were always most prominent in the tip one-third of the fruit. These ducts later became filled with a gummy substance which was probably a pentose, since the peach is known to form such substances.^{65*} Ducts of a similar nature were described by Ragland.^{56*} He found that they appeared at the apex of the fruit two to three weeks after full bloom and four weeks later had appeared thruout the flesh.

No detailed study was made of the development of these ducts. It seems probable that their formation was due, at least partly, to the inability of the vascular bundles to undergo the very significant stretching which results from the rapid increase in the size of the fruit.

The differentiation of stone tissue from flesh was evident at full bloom. The outline of the stone could be observed macroscopically two weeks after bloom. The stone began to harden first at the tip, down the ventral suture, and in the inner epidermis, with the tip slightly in advance of the other regions. Tests with alcoholic phloroglucin showed lignin formation accompanying hardening. Hardening progressed outward from the inner epidermis and from the tip toward the base. If the theory is accepted that the carpel is a modified leaf or leaf-like structure, it would be expected that the stone would harden first at the tip, since Fitzpatrick^{27*} has shown that, anatomically, the peach leaf matures first at the tip and then progressively toward the base.

The morphological details of ovule development after bloom were in agreement with the description of Pechoutre.^{52*} The more obvious features of its development are given in Table 1.

The skin and pubescence apparently followed the growth trend described by Dorsey and Potter,^{24*} altho this was not studied in detail. Microchemical tests showed the basal one-fourth to one-third of the hairs to be lignin, with the remainder giving a positive test for cellulose.

Physical Changes

Diameter. Both the C and the N fruits increased rapidly in diameter up to the 57th day after bloom, somewhat more slowly from the 57th to the 76th day, then at an increasing rate until a few days before harvest (Table 3). Hence the usual three periods of size increase were evident. There was a particularly noticeable acceleration from the 98th to the 112th day in the C fruits and from the 98th to 119th day in the N fruits. The period of slow growth was more pronounced in the polar diameter than in the suture and cheek diameters. During the early part of the third growth period all three diameters increased at approximately the same rate, but during the latter part of the period the suture and cheek diameters began to increase more rapidly than the polar diameter so that they both exceeded it at harvest.

The nitrogen had little effect on the diameter trend except that the fertilized fruits were usually slightly larger and had a 4-percent greater average diameter at harvest than the C fruits. The larger size of the N fruits at harvest was due to the fact that these fruits continued to grow after the cheek fruits had ripened (Table 3 and Fig. 2). The data of Blake *et al*^{6*} show this same condition in fruits growing under a wider range of nitrogen nutrition than the fruits in this investigation.

The different rates at which the three diameters increased during the season shows that the use of any one of them alone may lead to erroneous conclusions concerning rate of size increase. This is especially true of the long fruited varieties such as Elberta, when only the polar diameter is used, as has sometimes been the case.^{67*} The effect of nutritional level would also be a factor in such cases, since the nitrated fruits were broader in relation to length than the C fruits.

The transition from one growth period to the next was a gradual process, but it was more distinct between the first and second periods than between the second and third. This was also the case in previous work by the writer on this subject.^{39, 40*} Lilleland^{37*} says, "The changes in rate of growth are generally quite abrupt as the fruit passes from one period to the other." Tukey^{67*} also pointed out that the change from the first to second period was abrupt. This is not in agreement with the present data.

Volume. When volume increase was used as the measure of fruit development, the same period of reduced rate of increase occurred as with diameter measurements (Table 3 and Fig. 2). The N fruits were 23 percent larger than the C fruits at harvest, but until near harvest no appreciable difference occurred. The fact that, in contrast, the diameter difference at harvest was only 4 percent shows that vol-

TABLE 3.—DEVELOPMENT OF PEACH FRUIT DURING THREE GROWTH PERIODS

Growth period*	Date collected	Days after bloom	Polar diameter		Suture diameter		Cheek diameter		Volume		Fresh weight		Dry weight	
			C	N	C	N	C	N	C	N	C	N	C	N
I	4-14	0	.25	.25	.12	.10	.10	.01	.01	.007	.007	.007	.001	.001
	4-21	7	.40	.40	.30	.27	.27	.03	.03	.022	.022	.022	.004	.004
	4-28	14	.65	.70	.40	.35	.35	.08	.08	.076	.076	.076	.015	.015
	5-5	21	1.40	1.40	1.05	.90	.85	.53	.56	.49	.50	.49	.087	.088
	5-12	28	1.85	1.90	1.40	1.15	1.15	1.20	1.32	1.11	1.23	1.11	.211	.221
	5-19	35	2.40	2.44	1.88	1.58	1.66	3.40	3.80	3.19	3.57	3.19	.462	.493
	5-26	42	3.02	3.01	2.64	2.31	2.31	8.80	9.50	8.32	8.74	8.32	1.06	1.07
	6-2	49	3.55	3.63	3.15	2.77	2.98	16.48	18.20	15.62	17.01	15.62	2.03	2.05
II	6-10	57	3.98	3.88	3.47	3.11	3.11	21.72	22.28	21.22	21.55	21.22	3.37	3.28
	6-16	63	3.99	3.97	3.59	3.23	3.24	22.76	24.08	22.52	22.70	22.52	4.22	4.27
	6-22	69	4.01	4.04	3.72	3.28	3.34	26.16	26.52	25.83	26.39	25.83	5.79	5.75
	6-29	76	4.05	4.05	3.85	3.50	3.48	28.60	28.80	28.81	28.99	28.81	6.74	6.81
III	7-7	84	4.31	4.36	4.13	3.84	3.87	35.12	35.32	35.42	35.56	35.42	8.11	8.45
	7-15	92	4.52	4.59	4.60	4.21	4.24	44.80	45.00	45.02	45.74	45.02	9.90	10.42
	7-21	98	4.79	4.81	4.88	4.52	4.49	58.00	57.64	57.65	57.75	57.65	11.13	11.76
	7-29	106	5.48	5.35	5.61	5.45	5.12	87.00	83.80	85.80	82.62	85.80	14.98	15.35
	8-4	112	6.00	5.87	6.23	5.96	5.94	118.20	118.00	116.80	115.82	118.00	18.01	19.12
	8-9	117	6.05	6.05	6.28	6.13	6.13	130.68	128.30	128.30	128.30	128.30	19.71	20.00
	8-11	119	6.05	6.05	6.63	6.42	6.42	157.00	157.00	157.00	152.68	157.00	23.21	23.21
	8-15	123	6.08	6.08	6.67	6.48	6.48	160.28	160.28	160.28	155.23	160.28	23.94	23.94

C = fruit from cheek tree, N = fruit from nitrated tree.

*The first growth period extended to June 10, the second from June 10 to 29, and the third from June 29 to harvest.

TABLE 4.—DEVELOPMENT OF FLESH, STONE, AND KERNEL OF PEACH DURING THREE GROWTH PERIODS

Growth period	Date collected	Days after bloom	Volume		Fresh weight		Dry weight	
			C	N	C	N	C	N
Flesh								
			cc.	cc.	grams	grams	grams	grams
II	6-10	57	16.04	16.20	15.26	15.24	2.26	2.11
	6-16	63	17.08	18.00	16.42	17.15	2.44	2.38
	6-22	69	20.28	20.24	19.21	19.44	3.04	2.92
	6-29	76	22.80	22.60	21.96	21.75	3.32	3.22
III	7-7	84	29.28	29.08	28.38	27.97	4.02	4.00
	7-15	92	38.84	38.40	38.06	37.70	5.33	5.35
	7-21	98	52.16	51.16	50.44	49.78	6.52	6.54
	7-29	106	81.00	77.32	78.54	74.91	10.17	10.08
	8-4	112	112.40	112.20	109.55	108.61	13.11	14.07
	8-9	117	125.60	.....	121.91	.....	15.18	.....
	8-11	119	.....	151.32	.....	145.59	.....	18.08
	8-15	123	.....	154.60	.....	148.61	.....	19.10
Stone								
II	6-10	57	5.16	5.46	5.39	5.69	1.07	1.13
	6-16	63	5.10	5.48	5.54	5.93	1.74	1.85
	6-22	69	5.34	5.66	6.06	6.35	2.71	2.78
	6-29	76	5.22	5.60	6.27	6.62	3.37	3.54
III	7-7	84	5.28	5.62	6.46	6.96	4.02	4.38
	7-15	92	5.39	5.96	6.97	7.38	4.45	4.95
	7-21	98	5.28	5.84	6.62	7.32	4.46	5.06
	7-29	106	5.44	5.86	6.71	7.07	4.62	5.06
	8-4	112	5.20	5.20	6.64	6.59	4.67	4.80
	8-9	117	4.54	....	5.83	....	4.30	....
	8-11	119	....	5.10	....	6.48	....	4.86
	8-15	123	....	5.12	....	6.04	....	4.57
Kernel								
I	5-12	28	.04	.04	.036	.041	.005	.005
	5-19	35	.10	.12	.104	.120	.008	.009
	5-26	42	.22	.26	.226	.262	.016	.018
	6-2	49	.40	.50	.424	.504	.030	.034
II	6-10	57	.52	.62	.568	.622	.040	.042
	6-16	63	.58	.60	.560	.618	.040	.042
	6-22	69	.54	.62	.560	.604	.044	.046
	6-29	76	.58	.60	.576	.618	.052	.054
III	7-7	84	.56	.62	.576	.634	.072	.074
	7-15	92	.56	.64	.590	.656	.118	.120
	7-21	98	.56	.64	.586	.648	.150	.160
	7-29	106	.56	.62	.552	.638	.194	.206
	8-4	112	.60	.60	.608	.620	.230	.248
	8-9	117	.54	....	.556	....	.234	....
	8-11	119	....	.58	....	.606	....	.268
	8-15	123	....	.56	....	.580	....	.272

ume measurements give a more comprehensive picture of size increase than do diameter measurements.

After its separation from the stone was possible, the flesh volume paralleled that of the whole fruit, with the N flesh increasing more rapidly near maturity than the C flesh (Table 4). The flesh volume of the nitrated fruits was 23 percent greater in the last sample than that of the check fruits (Table 16).

The stone had reached nearly maximum volume when the period

TABLE 5.—AVERAGE DAILY INCREASES IN VOLUME AND WEIGHT OF ENTIRE PEACH FRUIT

Growth period	Date collected	Days after bloom	Volume		Fresh weight		Dry weight	
			C	N	C	N	C	N
			<i>cc.</i>	<i>cc.</i>	<i>grams</i>	<i>grams</i>	<i>grams</i>	<i>grams</i>
I	4-14	0						
	4-21	7	.002	.002	.002	.002	.0004	.0004
	4-28	14	.008	.008	.008	.008	.0016	.0016
	5-5	21	.067	.069	.060	.061	.0103	.0104
	5-12	28	.096	.109	.088	.104	.0177	.0190
	5-19	35	.314	.354	.297	.334	.0359	.0389
	5-26	42	.771	.814	.733	.740	.0854	.0824
	6-2	49	1.097	1.243	1.043	1.180	.1386	.1400
II	6-10	57	.655	.510	.700	.568	.1675	.1538
	6-16	63	.173	.300	.217	.358	.1416	.1650
	6-22	69	.567	.407	.552	.448	.2617	.2467
	6-29	76	.349	.326	.426	.371	.1357	.1529
III	7-7	84	.815	.815	.826	.821	.1713	.2050
	7-15	92	1.210	1.210	1.275	1.454	.2238	.2463
	7-21	98	2.200	2.107	2.005	2.002	.2050	.2233
	7-29	106	3.625	3.270	3.519	3.108	.4812	.4488
	8-4	112	5.200	5.700	5.167	5.535	.5217	.6283
	8-9	117	2.496	.....	2.300	.....	.3400	.....
	8-11	119	.....	5.571	.....	5.266	.....	.5843
	8-15	123	.....	.820	.....	.638	.....	.1825

of reduced rate of size increase in the fruit started. Thereafter the C stones increased only 4 percent and the N stones only 9 percent in volume. Both lots reached a maximum at approximately the time when the third period of size increase in the flesh started, and then decreased until harvest, the check stones decreasing 16 percent and the fertilized stones 14 percent in volume.

The kernels had also reached nearly their greatest volume when the period of slow size increase in the fruit began. They increased slowly thereafter—4 percent in the C kernels and 3 percent in the N kernels. At maturity the check kernels had decreased 7 percent and the nitrated kernels 13 percent from their maximum volume.

Fresh weight. The fresh weight followed the same general trend in the fruit and in its separate parts as did the volume, as shown in Tables 3 and 4.

Dry-matter. When development was measured on this basis there was no clearly defined period of reduced rate of growth of the fruit (Tables 3 and 5 and Fig. 2) such as was shown by diameter, volume, and fresh-weight determination. The rate did increase, however, during the last few weeks, with the exception of the final sample, in which a decrease occurred (Table 5). No consistent difference prevailed between the C and N fruits until the last few samples, when the rate in the N fruits became more rapid, with the result that they had a 22-percent greater dry weight than the C fruits at harvest.

The flesh had a period of reduced rate of dry-weight increase, coinciding with that obtained by the other methods of measurement, but showed a rapid acceleration before harvest (Table 6 and Fig. 3).

The flesh of the nitrated fruits had a 26-percent greater dry weight at maturity than the flesh of the C fruits.

The stone made the greatest dry-weight increase while the flesh was making the slowest, and was decreasing in dry weight when the flesh was increasing rapidly just before ripening (Table 6 and Fig. 3). The nitrated stones had a 6-percent greater dry weight than the check stones in the last sample.

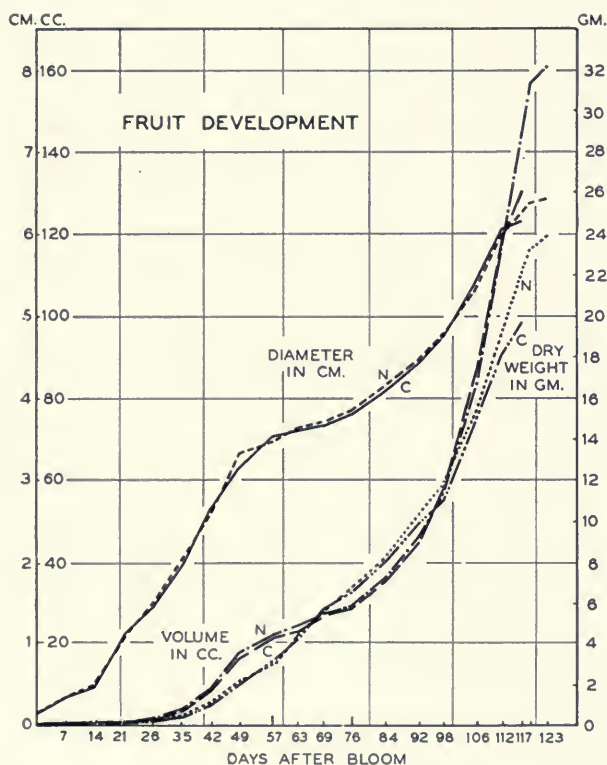


FIG. 2.—SEASONAL CHANGES IN SIZE AND DRY WEIGHT OF WHOLE FRUIT FROM THE TWO EXPERIMENTAL PEACH TREES

The kernel increased rapidly in dry weight during the first period, when it was at its maximum acceleration in size, but increased very slowly during the first half of the second period, coincident with the enlargement of the endosperm and embryo. The greatest rate of dry-weight increase in the kernel followed the attainment of maximum size by the embryo. The N kernels had a 16-percent greater dry weight than the C kernels in the last collection.

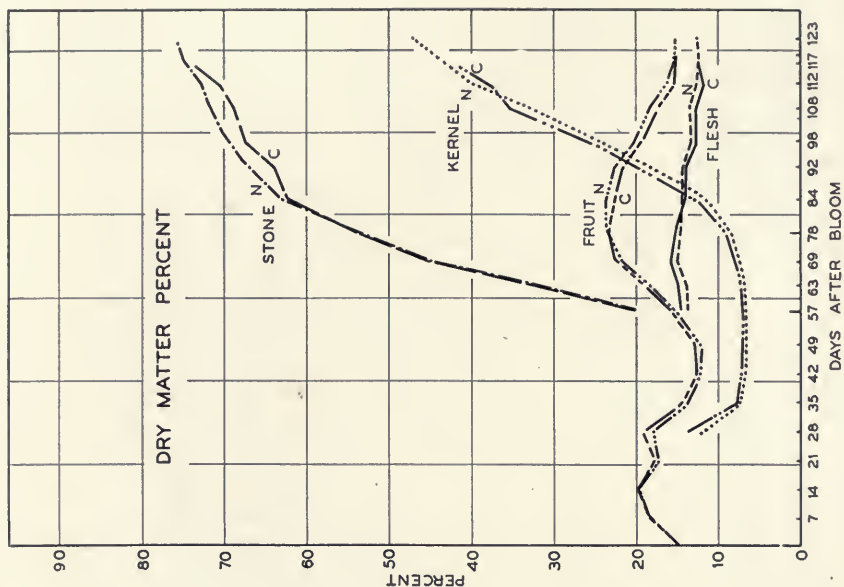


FIG. 4.—SEASONAL CHANGES IN PERCENTAGE OF DRY MATTER IN WHOLE FRUIT AND IN FLESH, STONE, AND KERNEL

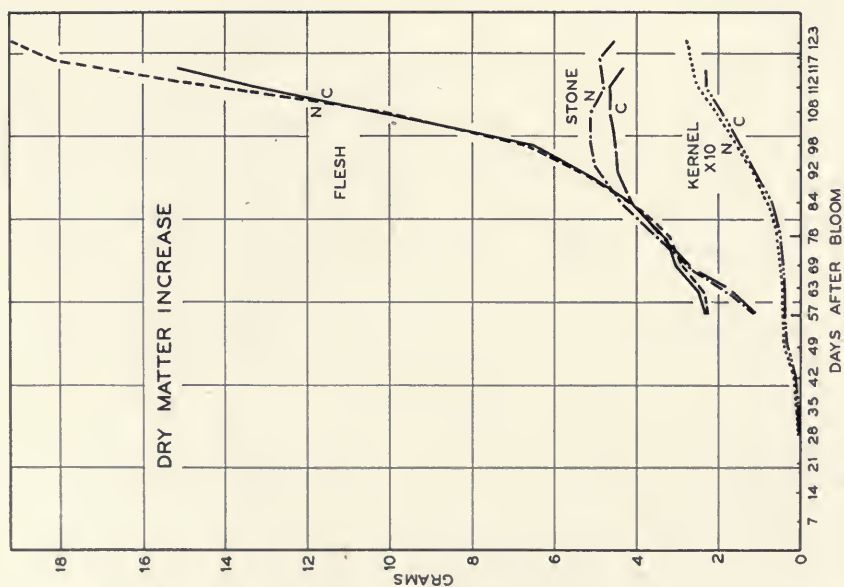


FIG. 3.—SEASONAL CHANGES IN DRY-MATTER CONTENT OF PEACH FLESH, STONE, AND KERNEL

TABLE 6.—AVERAGE DAILY INCREASES IN VOLUME AND WEIGHT OF PARTS OF PEACH FRUIT

Growth period	Date collected	Days after bloom	Volume		Fresh weight		Dry weight	
			C	N	C	N	C	N
Flesh only								
			cc.	cc.	grams	grams	grams	grams
II	6-10	..	.....	.....	.....	.....	.....	.....
	6-16	63	.173	.300	.193	.318	.0300	.0450
	6-22	69	.533	.373	.465	.382	.1000	.0900
	6-29	76	.360	.337	.393	.330	.0400	.0429
III	7-7	84	.810	.810	.803	.778	.0875	.0975
	7-15	92	1.193	1.165	1.210	1.216	.1638	.1688
	7-21	98	2.220	2.127	2.063	2.013	.1983	.1983
	7-29	106	3.605	3.270	3.513	3.141	.4563	.4425
	8-4	112	5.233	5.813	5.168	5.617	.4900	.6650
	8-9	117	2.640	.....	2.472	.....	.4140	.....
	8-11	119	.....	5.589	.....	5.283	.....	.5729
	8-15	123	.....	.820	.....	.755	.....	.2550
Stone only								
II	6-10	..	.....	.....	.....	.....	.....	.....
	6-16	63	-.010	.003	.025	.040	.1117	.1200
	6-22	69	.040	.030	.087	.070	.1617	.1550
	6-29	76	-.017	-.009	.030	.039	.0943	.1086
III	7-7	84	.008	.003	.024	.043	.0813	.1050
	7-15	92	.014	.043	.064	.053	.0538	.0713
	7-21	98	-.018	-.020	-.058	-.010	.0017	.0183
	7-29	106	.020	.003	.011	-.031	.0200	.0000
	8-4	112	-.040	-.110	-.012	-.080	.0083	-.0433
	8-9	117	-.132	.....	-.162	.....	-.0742	.....
	8-11	119	.....	-.014	.....	-.016	.....	.0086
	8-15	123	.....	.005	.....	-.110	.....	-.0725
Kernel only								
I	5-12	..	.....	.....	.....	.....	.....	.....
	5-19	35	.009	.011	.010	.011	.0004	.0006
	5-26	42	.017	.020	.017	.020	.0011	.0013
	6-2	49	.026	.034	.028	.035	.0020	.0023
II	6-10	57	.015	.015	.018	.015	.0013	.0010
	6-16	63	.010	-.003	-.001	-.001	.0000	.0000
	6-22	69	-.007	.003	.000	-.002	.0007	.0007
	6-29	76	.006	-.003	.002	.002	.0011	.0011
III	7-7	84	-.003	.003	.000	.002	.0025	.0025
	7-15	92	.000	.003	.002	.003	.0058	.0058
	7-21	98	.000	.000	-.001	-.001	.0053	.0067
	7-29	106	.000	-.003	-.004	-.001	.0055	.0058
	8-4	112	.007	-.003	.009	-.003	.0060	.0070
	8-9	117	-.012	.....	-.010	.....	.0008	.....
	8-11	119	.....	-.003	.....	-.002	.....	.0029
	8-15	123	.....	-.005	.....	-.007	.....	.0010

Dry-matter percentage. The percent of dry matter in the whole fruit was high for a few weeks following bloom, apparently coincident with the duration of rapid cell division, and then decreased to the end of the first growth period (Table 7 and Fig. 4). The percent in the flesh increased in the second period at the time that the walls of the flesh cells increased in thickness,^{1*} and decreased thereafter, with the exception of the last sample, in which an increase occurred owing probably to the rapid accumulation of sugar at that time (Table 9).

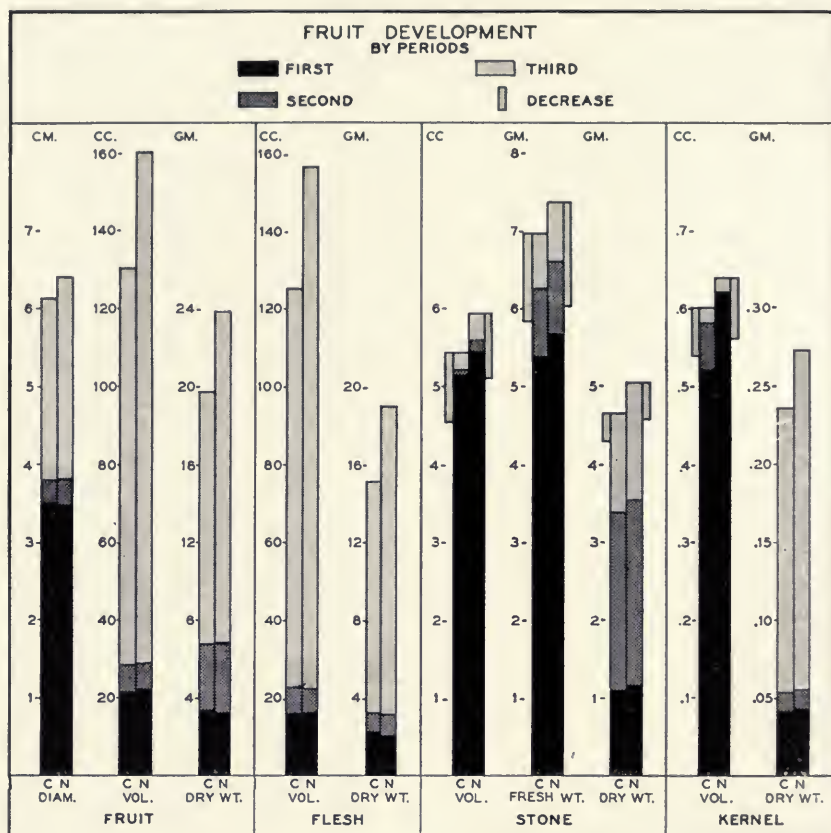


FIG. 5.—CHANGES IN DEVELOPMENT OF WHOLE FRUIT AND FRUIT PARTS
DURING THE THREE GROWTH PERIODS

A very significant acceleration in rate of accumulation of dry matter is shown in the data on the stone. The percent increased from the first separation of the stone from the flesh until the end of the season, but the rate of increase was greatest in the second growth period. Beginning with the first separation of the kernel from the rest of the fruit 28 days after bloom, the percent of dry matter in the kernel decreased to the end of the first period. This was undoubtedly due to the enlargement of the cells during this time. The percent of dry matter in the kernel increased from the start of the second period until harvest, the greatest rate of increase coinciding with the rapid accumulation of ether extract in the third growth period (Table 14).

Consideration of the relative proportions of flesh, stone, and kernel in the fruit shows that on the fresh-weight basis the flesh always

TABLE 7.—DRY MATTER IN PEACH FRUIT AS PERCENT OF FRESH WEIGHT

Growth period	Date collected	Days after bloom	Entire fruit		Flesh		Stone		Kernel	
			C	N	C	N	C	N	C	N
I	4-14	0	14.29	14.29	.....	.....	.....	.....	.....	.....
	4-21	7	18.18	18.18	.....	.....	.....	.....	.....	.....
	4-28	14	19.74	19.74	.....	.....	.....	.....	.....	.....
	5-5	21	17.75	17.60	.....	.....	.....	.....	.....	.....
	5-12	28	19.18	17.97	19.07 ^a	18.05 ^a	.....	.....	13.89	12.20
	5-19	35	14.48	13.81	14.69 ^a	14.03 ^a	.....	.....	7.69	7.50
	5-26	42	12.74	12.24	12.84 ^a	12.38 ^a	.....	.....	7.08	6.87
	6-2	49	12.97	12.05	13.17 ^a	12.17 ^a	.....	.....	7.08	6.75
II	6-10	57	15.88	15.22	14.81	13.85	19.85	19.86	7.04	6.75
	6-16	63	18.74	18.02	14.86	13.88	31.41	31.20	7.14	6.80
	6-22	69	22.42	21.79	15.83	15.02	44.72	43.78	7.86	7.62
	6-29	76	23.39	23.49	15.12	14.80	53.75	53.47	9.03	8.74
III	7-7	84	22.90	23.76	14.16	14.30	62.23	62.93	12.50	11.67
	7-15	92	21.70	22.78	14.00	14.19	63.85	67.07	20.00	18.29
	7-21	98	19.31	20.36	12.93	13.14	67.37	69.13	25.60	24.69
	7-29	106	17.46	18.58	12.95	13.46	68.85	71.57	35.14	32.29
	8-4	112	15.42	16.51	11.97	12.95	70.33	72.84	37.83	40.00
	8-9	117	15.36	.....	12.45	.....	73.76	.....	42.09	.....
	8-11	119	.....	15.20	.....	12.42	.....	75.00	.....	44.22
	8-15	123	.....	15.42	.....	12.85	.....	75.66	.....	46.90

^aFlesh and stone combined.

constituted over 70 percent of the fruit and when ripe constituted over 95 percent (Table 8). The stone and kernel made up less than 30 percent of the fruit in the first separation from the flesh and less than 5 percent in the ripe fruit. This would indicate that these parts are relatively insignificant in comparison with the flesh in the development of the fruit. A quite different picture is obtained, however, when the calculations are made on a dry-matter basis (Table 8). The flesh constituted less than 50 percent of the fruit for two weeks near the end of the second growth period. At this time the stone was near to its greatest dry weight. Thus the stone formed a very significant part of the fruit during the second period. These observations emphasize the necessity of dry-matter determination in organs such as the stone and kernel, in which the density changes during the period under consideration.

Necessity for dry-matter determinations. From the results discussed above and the data shown in Tables 3 to 8 and Figs. 2 to 5 it will be seen that the changes in dry matter must be determined to obtain an accurate expression of the physiology of the growth of the peach fruit. Diameter and volume determinations can only show the changes which occur in size, and cannot, therefore, give any indication of changes which have been shown to occur in the percent of solids in all parts of the peach at certain stages in their development. The close agreement between the fresh weight and the volume of the fruit throughout the season, as seen in Table 3 and substantiated by previous work,^{39, 40*} shows that fresh-weight determinations are no better as measures of the growth of the fruit. Because of temporary fluctua-

TABLE 8.—RELATIVE PROPORTIONS OF FLESH, STONE, AND KERNEL IN PEACH FRUIT

Growth period	Date collected	Days after bloom	Percent of fresh weight of fruit in—						Percent of dry weight of fruit in—					
			Flesh			Stone			Kernel			Flesh		
			C	N		C	N		C	N		C	N	
I	5-12	28	.....	.....	.....	.....	.....	.....	3.24	3.33	.....	.....	.....	.....
	5-19	35	.....	.....	.....	.....	.....	.....	3.26	3.36	.....	.....	.....	.....
	5-26	42	.....	.....	.....	.....	.....	.....	2.72	3.00	.....	.....	.....	.....
	6-2	49	.....	.....	.....	.....	.....	.....	2.71	2.96	.....	.....	.....	.....
II	6-10	57	71.91	70.72	25.40	26.39	2.68	2.89	67.06	64.33	31.75	34.45	1.19	1.28
	6-16	63	72.91	72.36	24.60	25.02	2.49	2.61	57.82	55.74	41.23	43.33	.95	.98
	6-22	69	74.37	73.66	23.46	24.06	2.17	2.29	52.50	50.78	46.80	48.35	.76	.80
	6-29	76	76.22	75.03	21.76	22.84	2.00	2.13	49.26	47.28	50.00	51.98	.77	.79
III	7-7	84	80.12	78.66	18.24	19.57	1.63	1.78	49.57	47.34	49.57	51.83	.89	.88
	7-15	92	83.43	82.42	15.28	16.13	1.29	1.43	53.84	51.34	44.95	47.50	1.19	1.15
	7-21	98	87.49	86.20	11.48	12.68	1.02	1.12	58.58	55.61	40.07	43.04	1.35	1.36
	7-29	106	91.54	90.67	7.82	8.56	.64	.77	67.89	65.67	30.84	32.96	1.30	1.34
	8-4	112	93.79	93.77	5.68	5.69	.52	.54	72.79	73.59	25.93	25.10	1.28	1.30
	8-9	117	95.02	.....	4.54	.....	.43	.....	77.02	.....	21.82	.....	1.19	.....
	8-11	119	.....	95.36	.....	4.24	.....	.39	.....	77.90	.....	20.94	.....	1.15
	8-15	123	.....	95.74	.....	3.89	.....	.37	.....	79.78	.....	19.09	.....	1.14

tions of water content, it is even possible to obtain a decrease in fresh weight while the amounts of solids are actually increasing.

Diameter measurements must be resorted to when the development of specific fruits on the tree is followed, but in such cases the dry-matter increase in comparable fruits must be determined in order to make correct physiological interpretation possible.

The developmental history of flesh, stone, and kernel, as depicted in Table 4 and Figs. 3 and 5 emphasizes the necessity for dry-matter determinations and for separating the fruit into its parts in studies of its physiological development. Increases in dry-matter percentage in the stone and the kernel in the second and third growth periods made possible the most rapid dry-matter increases after these parts had reached nearly their maximum volumes and fresh weights. Measurements of size and fresh weight could not show these increases, nor could they show the increase in dry-matter percentage in the flesh in the second growth period and its decrease in the third period. This is in agreement with previous work.^{40*}

Measurements are particularly inadequate as indices of the growth of the kernel because of the internal tissue changes which occur during development, as shown in Table 1. For example, the kernel near the end of the first growth period is a vastly different organ than at the beginning of the third growth period. The inclusion of measurements of endosperm and embryo development would provide little information of their metabolic activity. There seems to be no good reason for relying upon diameter or volume determinations in the stone and kernel, since the fruit must be destroyed to obtain them, and securing the dry weight merely adds the simple operations of weighing and drying.

Chemical Changes

The chemical data secured from this investigation are presented as percentages of fresh weight and as amounts per fruit or fruit part. Percentages of dry weight are also given in Tables 17 and 18 for reference. Expressing results solely on a percentage basis does not always give a true picture of the seasonal activity of any particular constituent. This is especially true of organs, such as fruits, which increase many times in mass during the course of their development.^a

Sugars. Altho it is possible that reducing substances other than sugars were present in the extracts, it is probable that the quantity of them was small. Therefore the term "reducing sugars" will be used here rather than the more cumbersome but perhaps more correct term "free reducing substances." Because of the relationship that existed

*In this publication the term *amount* refers to grams per 100 fruits; *percent* refers to fresh weight percentage; and *content* refers to both amount and percent when they have the same seasonal trend.

TABLE 9.—SUGAR CONTENT OF PEACH FRUIT

Growth period	Date collected	Days after bloom	Percent of fresh weight				Grams per 100 fruits			
			C		N		C		N	
			Re- ducing sugars	Su- crose	Re- ducing sugars	Su- crose	Re- ducing sugars	Su- crose	Re- ducing sugars	Su- crose
Flesh ^a										
I	4-14	0	2.74	.47	2.84	.42	.42	.07	.43	.06
	4-21	7	1.00	.34	.93	.31	.02	.01	.02	.01
	4-28	14	.91	.30	.83	.31	.07	.02	.06	.02
	5-5	21	1.90	.14	1.86	.13	.94	.07	.93	.07
	5-12	28	3.66	.17	3.51	.10	3.95	.18	4.18	.12
	5-19	35	3.44	.10	3.34	.13	10.63	.31	11.52	.45
	5-26	42	3.41	.15	3.31	.15	27.63	1.21	28.07	1.28
	6-2	49	3.99	.35	3.63	.26	60.61	5.32	59.93	4.29
II	6-10	57	4.07	.44	3.76	.42	62.11	6.71	57.30	6.40
	6-16	63	4.24	.32	3.77	.40	69.62	5.26	64.66	6.86
	6-22	69	4.54	.15	4.12	.33	87.21	2.88	80.09	6.42
	6-29	76	4.22	.26	4.06	.27	92.67	5.71	88.31	5.87
III	7-7	84	4.05	.54	3.87	.67	114.94	15.32	108.24	18.74
	7-15	92	3.86	.45	3.85	.43	146.90	17.14	145.15	16.21
	7-21	98	3.69	1.09	3.67	1.03	186.12	54.98	182.69	51.28
	7-29	106	3.91	1.67	3.61	1.69	307.09	131.16	270.43	126.59
	8-4	112	3.94	2.09	3.59	2.52	431.63	228.96	389.91	273.70
	8-9	117	3.45	4.50	....	....	420.59	548.59	....	....
	8-11	119	....	....	3.05	4.16	....	....	444.05	605.65
	8-15	123	....	....	2.93	4.94	....	....	435.43	734.13
Stone										
II	6-10	57	2.50	.28	2.49	.76	13.48	1.50	14.17	4.32
	6-16	63	2.06	.19	1.98	.22	11.41	1.06	11.74	1.31
	6-22	69	1.30	.55	1.20	.35	7.88	3.33	7.62	2.22
	6-29	76	1.06	.35	.90	.65	6.64	2.20	5.96	4.30
III	7-7	84	.81	.42	.72	.09	5.23	2.72	5.01	.63
	7-15	92	.72	.17	.66	.11	5.02	1.18	4.87	.81
	7-21	98	.66	.11	.68	.11	4.37	.73	4.98	.80
	7-29	106	.67	.12	.61	.09	4.50	.80	4.31	.64
	8-4	112	.63	.18	.51	.11	4.18	1.20	3.36	.73
	8-9	117	.52	.20	....	....	3.03	1.17	....	....
	8-11	119	....	....	.41	.12	....	....	2.66	.77
	8-15	123	....	....	.42	.11	....	....	2.54	.66
Kernel										
I	5-12	28	2.11	1.42	1.80	1.56	.08	.05	.07	.06
	5-19	35	1.03	.63	.97	.70	.11	.06	.12	.08
	5-26	42	.75	.31	.72	.32	.17	.07	.19	.09
	6-2	49	.71	.20	.71	.30	.30	.09	.36	.15
II	6-10	57	.64	.30	.56	.30	.36	.17	.35	.19
	6-16	63	.63	.26	.54	.27	.35	.15	.33	.17
	6-22	69	.68	.26	.56	.23	.38	.15	.34	.14
	6-29	76	.87	.55	.73	.68	.50	.32	.45	.42
III	7-7	84	.93	1.00	.74	.98	.54	.57	.47	.62
	7-15	92	1.69	.76	1.53	.53	1.00	.45	1.00	.35
	7-21	98	1.58	.84	1.54	.69	.93	.49	1.00	.45
	7-29	106	1.51	.78	1.53	.76	.83	.43	.98	.48
	8-4	112	1.65	.99	1.86	.98	1.00	.60	1.15	.61
	8-9	117	1.78	2.05	....	....	.99	1.14	....	....
	8-11	119	....	....	1.99	1.18	....	....	1.21	.72
	8-15	123	....	....	2.10	1.65	....	....	1.22	.96

^aN. B. Under "flesh" in this and subsequent tables, 4-14 = blossoms; 4-21 to 5-5 inclusive = entire fruit; 5-12 to 6-2 inclusive = flesh plus stone; 6-10 to 8-15 inclusive = flesh alone. All carbohydrates are calculated and expressed as dextrose.

between reducing sugars and sucrose it seems desirable to consider their activity together.

The seasonal trend of sugars in the separate parts of the fruit is shown in Table 9 and Figs. 6 and 7. The relatively small percent and amount of sucrose in the flesh until well into the third growth period indicates the continued use of sugars in the metabolism of the fruit. The processes of cell division, cell enlargement and cell-wall thickening during this time would require increasingly large quantities of sugars. Consequently there was no excess available for condensation and storage as sucrose until the above processes had neared completion. During the third growth period, however, when the fruit was nearing maturity, the sucrose content increased rapidly and exceeded the reducing sugars

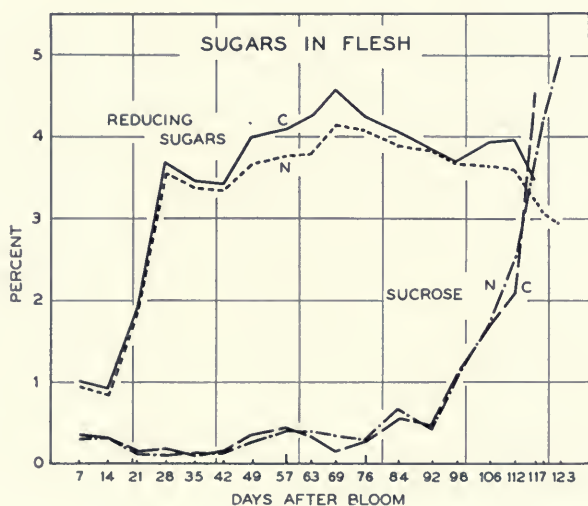


FIG. 6.—SEASONAL CHANGES IN PERCENTAGE OF SUGARS IN FLESH OF PEACH ON FRESH BASIS

at harvest. This behavior of sugars in the flesh is in agreement with the results of Nightingale,^{51*} Kokin,^{35*} and Lott.^{39, 40*} As was mentioned in the literature review, the peach is one of the few fruits in which sucrose is the predominant sugar in the ripe fruit. That this condition does not prevail much beyond the soft ripe condition is indicated by the statement of Tarr^{62*} that, "as the 'so-called' dead ripe stage occurs, the sucrose content decreases very rapidly with a corresponding increase in reducing sugars." Bigelow and Gore^{4*} also seemed to find this condition in stored peaches. This fact, in addition to the loss of aromatic compounds, is the probable reason for some of the

TABLE 10.—STARCH AND DEXTRIN CONTENT OF PEACH FRUIT

Growth period	Date collected	Days after bloom	Percent of fresh weight						Grams per 100 fruits					
			Flesh			Stone			Flesh			Stone		
			C	N	C	C	N	C	C	N	C	C	N	C
I	4-14 ^a	0	.44	.46	...	...	...	...	.07	.07	...	...	...	...
	4-21	7	.40	.43	...	...	...	...	.01	.01	...	...	...	...
	4-28	14	.39	.39	...	...	...	...	.03	.03	...	...	...	...
	5-5	21	.65	.46	...	...	...	...	.32	.23	...	...	...	...
	5-12	28	.99	.89	...	3.53	3.16	...	1.06	1.06	...	...	...	.13
II	5-19	35	.69	.60	...	1.45	1.35	...	2.13	2.07	...	...	...	.16
	5-26	42	.55	.46	...	.71	.73	...	4.45	3.91	...	...	...	.19
	6-2	49	.48	.46	...	.61	.68	...	7.30	7.59	...	...	...	.34
	6-10	57	.81	.68	.39	.63	.69	...	12.36	10.36	2.10	1.59	...	.36
	6-16	63	.77	.60	.48	.48	.53	...	12.64	10.29	2.66	2.13	...	.43
III	6-22	69	.83	.66	.58	.34	.46	...	15.94	12.83	3.51	2.16	...	.33
	6-29	76	.44	.58	.70	.64	.64	...	9.66	12.62	4.39	3.18	...	.28
	7-7	84	.32	.29	.62	.53	.77	...	9.08	8.11	4.01	3.69	...	.40
	7-15	92	.36	.53	.73	.66	.67	...	13.70	19.98	5.09	4.87	...	.49
	7-21	98	.30	.43	.57	.68	.62	...	15.13	21.41	3.77	4.98	...	.47
	7-29	106	.33	.39	.67	.64	.45	...	25.92	29.21	4.50	4.52	...	.36
	8-4	112	.28	.30	.60	.51	.62	...	30.67	32.58	3.98	3.36	...	.39
	8-9	117	.17	...	.54	...	.51	...	20.72	...	3.15	...	...	.38
	8-11	119	...	.25	...	.64	.67	...	...	36.40	...	4.15	...	.41
	8-15	123	...	.22	...	.64	.65	...	...	32.69	...	3.87	...	.38

^aFlowers.

deterioration in quality as peaches become overripe. The loss of sugars and acid thru respiration would be an added factor.

The rapidity of influx of sucrose during the final swell is shown by the fact that 75 percent of the total amount of sucrose in the ripe flesh accrued in the last 11 days in the C fruits, whereas 65 percent accumulated in the flesh of the N fruits in the same interval.

The content of reducing sugars in the stone was greater in each sample than the sucrose; which fact indicates that there was practically no storage of carbohydrates as sucrose in the stone. The consistent decrease of sugars in the stone thruout the second and third growth periods does not necessarily show that little sugar entered the stone during this time, but rather that the sugar probably condensed immediately to more complex carbohydrates until the maximum dry weight of the stone was reached, and was translocated to the flesh or kernel or both thereafter. The above relationship of reducing sugars and sucrose in the stone, and their seasonal trend, is in agreement with previous investigations.^{39, 40*}

In the kernel reducing sugars were more abundant than sucrose until just before harvest, when the amount became approximately the same as sucrose. An interesting feature of the trend of sugars in the kernel was the rapid increase in amount during the first period as the nucellus and integuments were enlarging to nearly maximum size, followed by a decrease during the early size increase of the endosperm and embryo and a very slow rate of increase thereafter until the embryo had reached nearly its greatest size. The fact that sucrose did not increase appreciably until the rate of accumulation of ether extract had materially slowed down is evidence that the sugars were being used as a source of ether extract.

Starch and dextrin. This carbohydrate fraction formed a comparatively small part of the total carbohydrates determined, altho the values obtained were considerably higher than those reported by Nightingale^{51*} and Tarr.^{62*} Comparison of the percentages and amounts in the flesh emphasizes the possibility of errors in interpretation when percentage alone is used as the measure of the trend of a constituent. Altho there was a very large decrease in the percentage in the third growth period, the amount more than doubled (Table 10).

Microchemical tests showed that in the young fruit there was no starch in the four or five cell layers of the hypodermis, and that it was most concentrated in a region of ten to fifteen layers of cells interior to the hypodermis. It was also abundant at the base of the fruit just above the point of attachment to the receptacle. Very little could be detected in the stone or kernel at any time. A positive test in the flesh was obtained on July 21, 98 days after bloom, but not thereafter. The region of distribution in the flesh remained the same thruout the season.

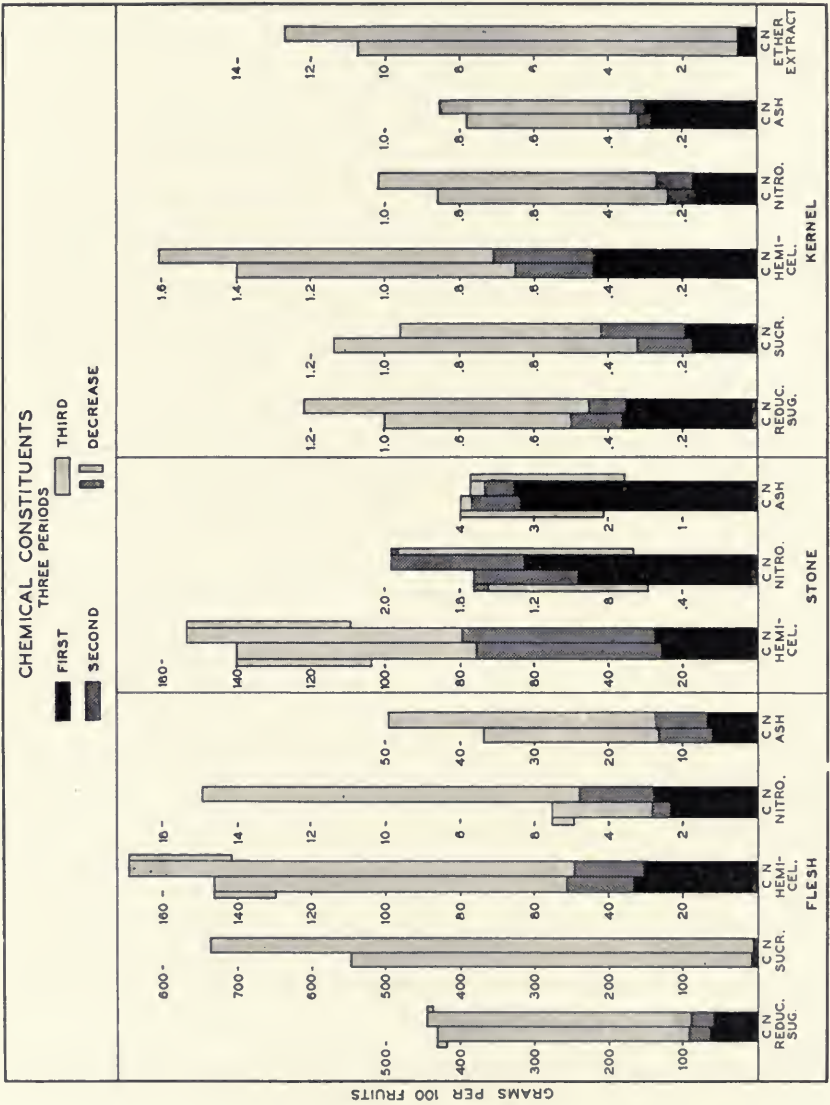


FIG. 7.—CHEMICAL CHANGES IN FLESH, STONE, AND KERNEL DURING THE THREE GROWTH PERIODS

Hemicellulose. Altho this fraction, as determined, was really insoluble acid-hydrolyzable materials other than starch and dextrin, it has frequently been designated as hemicellulose^{46, 65*} and for convenience will be referred to as such in this manuscript.

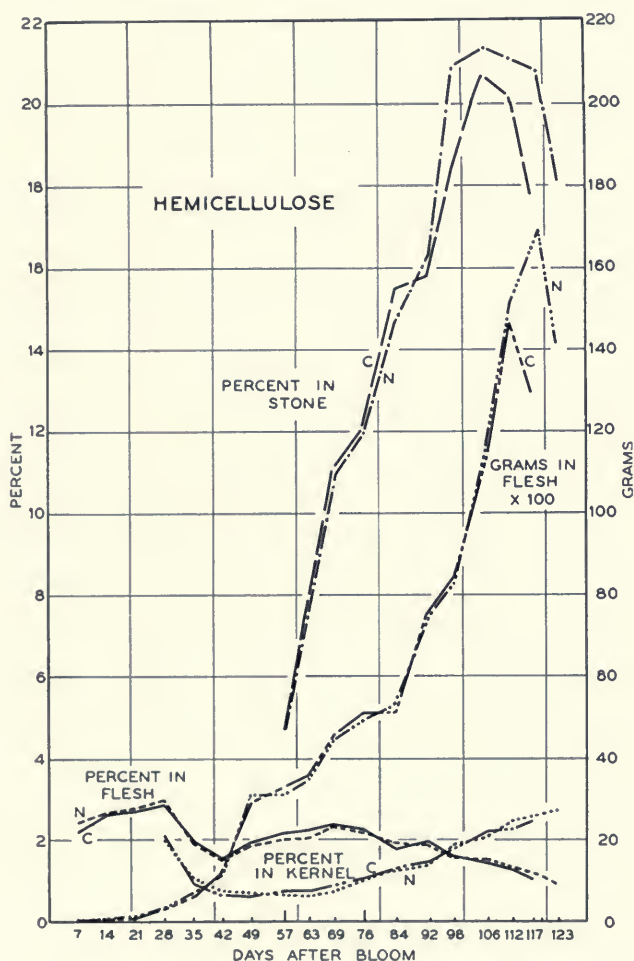


FIG. 8.—SEASONAL CHANGES IN HEMICELLULOSE CONTENT OF FLESH, STONE, AND KERNEL ON FRESH BASIS

The data shown in Table 11 and Figs. 7 and 8 emphasize the importance of expressing results in terms of amounts, as well as in percentages, in organs such as fruits, which change appreciably in mass during the season. Altho the percent of hemicellulose in the flesh

TABLE 11.—HEMICELLULOSE CONTENT OF PEACH FRUIT

Growth period	Date collected	Days after bloom	Percent of fresh weight						Grams per 100 fruits					
			Flesh			Kernel			Flesh			Stone		
			C	N	C	C	N	C	C	N	C	C	N	C
I	4-14*	0	2.68	2.68	.....	.....	.....	.....	.41	.40	.....	.....	.....	.....
	4-21	7	2.24	2.44	.....	.....	.....	.....	.05	.05	.....	.....	.....	.....
	4-28	14	2.67	2.64	.....	.....	.....	.....	.20	.20	.....	.....	.....	.....
	5-5	21	2.70	2.79	.....	.....	.....	.....	1.33	1.40	.....	.....	.....	.....
	5-12	28	2.85	2.99	.....	.....	.....	.....	3.08	3.56	.....	.....	.....	.....
	5-19	35	1.99	1.95	.....	.....	.....	.....	6.15	6.73	.....	.....	.....	.08
	5-26	42	1.58	1.47	.....	.....	.....	.....	12.80	12.47	.....	.....	.....	.10
II	6-2	49	1.93	1.90	.....	.....	.....	.....	29.32	31.37	.....	.....	.....	.15
	6-10	57	2.18	2.01	.....	.....	.....	.....	33.27	30.63	.....	.....	.....	.34
	6-16	63	2.21	2.05	.....	.....	.....	.....	36.29	35.16	.....	.....	.....	.44
	6-22	69	2.39	2.34	.....	.....	.....	.....	45.91	45.49	.....	.....	.....	.44
	6-29	76	2.33	2.25	.....	.....	.....	.....	51.17	48.94	.....	.....	.....	.48
	7-7	84	1.79	1.91	.....	.....	.....	.....	50.80	53.42	.....	.....	.....	.71
	7-15	92	1.99	1.97	.....	.....	.....	.....	75.74	74.27	.....	.....	.....	.85
III	7-21	98	1.66	1.65	.....	.....	.....	.....	83.73	82.14	.....	.....	.....	1.00
	7-29	106	1.44	1.55	.....	.....	.....	.....	113.10	116.11	.....	.....	.....	1.21
	8-4	112	1.33	1.39	.....	.....	.....	.....	145.70	150.97	.....	.....	.....	1.35
	8-9	117	1.06	1.16	.....	.....	.....	.....	129.22	133.80	.....	.....	.....	1.55
	8-11	119	.....	.95	.....	.....	.....	.....	.....	103.66	.....	.....	.....	1.38
	8-15	123	.....	.....	.....	.....	.....	.....	.....	134.65	.....	.....	.....	1.60
			.....	.....	.....	.....	.....	.....	.....	141.17	.....	.....	.....	1.61

*Flowers.

decreased from about the middle of the second period until maturity, the amount increased thruout the season, with the exception of the last sample, in which a moderate decrease occurred. Nightingale^{51*} reported a decrease in the percent of hemicellulose in the flesh of Elberta during the third growth period, but he did not calculate the total amount; hence it is not possible to determine whether the total amount actually increased or decreased. His determinations are not strictly comparable with the present data because he extracted pectin before determining hemicellulose, but he also reported a decrease in pectin. In both Hiley and Elberta in Mississippi there was a moderate drop in the amount of hemicellulose in the flesh during the final swell in each¹ of the two seasons 1932 and 1933.^{39, 40*} This shows the need for study of different varieties under varying environmental conditions before generalizations should be considered.

A striking feature of the hemicellulose data was the rapid accumulation in the stone in the second growth period and the decrease in the third period. Such a condition was found in previous investigations.^{39, 40*} This increase occurred concomitantly with the lignification of the stone and the increase in dry weight, while the decrease coincided with the decrease in dry weight (Table 4). The decrease in the amount of hemicellulose in the stone in the third period indicates that a part of it acted as a reserve carbohydrate and was translocated probably to the flesh or to the kernel or to both.

The increase in both the percentage and the amount of hemicellulose in the kernel during the third growth period indicates that it may be a reserve food in the kernel, used in the growth of the young seedling. The stationary condition at the beginning of the second growth period, which coincided with a decrease in sugars and in starch and dextrin in the kernel, indicates that all available carbohydrates were being consumed in the growth of the endosperm and embryo.

Nitrogen. In spite of a consistently decreasing percentage, the amount of nitrogen in the flesh of the fertilized fruits increased from bloom to maturity, and the amount in the flesh of the check fruits increased almost to maturity (Table 12 and Fig. 9). This shows that the developing fruit continued to assimilate nitrogen thruout the season, with the exception of the C flesh in the last two samples. That the assimilated amounts were used in increased fruit growth is shown by the association between the amount assimilated and the greater size and dry weight of the ripe flesh of the nitrated as compared with the check fruit. The same relationship existed in the stone and kernel. Nightingale^{52*} also reported a much higher percentage of nitrogen in the flesh of high-nitrogen fruits than of high-carbohydrate fruits.

The higher percentages in the kernel than in the flesh or the stone and in the N kernels than in the C kernels indicates a greater need for nitrogen in the kernel in its development. The much greater amount

Flowers.

in the kernel than in the stone at harvest shows a greater storage in the kernel. The decreasing amount in the stone after the middle of the second growth period shows that the stone reached physiological ma-

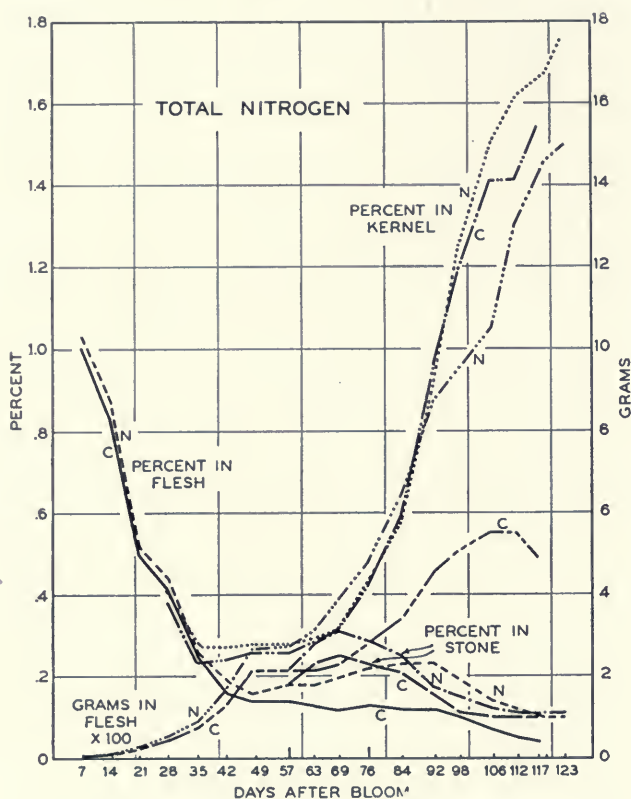


FIG. 9.—SEASONAL CHANGES IN NITROGEN CONTENT OF FLESH, STONE, AND KERNEL ON FRESH BASIS

turity long before the flesh and kernel. These relationships were also found to exist in the previous work by the author.^{40*}

Ash. As might be expected because of the greater size of the flesh, the amount of ash in the flesh was greater thruout the season than in the stone and kernel. The percentage in the flesh, however, was approximately the same as that in the stone, while that in the kernel at harvest was over four times as great as that in either flesh or stone (Table 13 and Fig. 10). The amount in both flesh and kernel

TABLE 13.—ASH CONTENT OF PEACH FRUIT

Growth period	Date collected	Days after bloom	Percent of fresh weight						Grams per 100 fruits					
			Flesh			Stone			Flesh			Stone		
			C	N		C	N		C	N		C	N	
I	4-14 ^a	0	.91	.88	....	....	....	....	.02	.02	....	....	....	....
	4-21	7	1.70	1.79	....	....	....	....	.04	.04	....	....	....	....
	4-28	14	1.45	1.57	....	....	....	....	.11	.12	....	....	....	....
	5-5	21	.84	.89	....	....	....	....	.41	.45	....	....	....	....
	5-12	28	.63	.67	....	.68	.73	....	.68	.80	....	....	....	.02
	5-19	35	.47	.49	....	.54	.57	....	1.45	1.69	....	....	....	.06
	5-26	42	.37	.37	....	.55	.55	....	2.99	3.14	....	....	....	.12
II	6-2	49	.33	.34	....	.54	.50	....	5.02	5.61	....	....	....	.23
	6-10	57	.40	.44	....	.58	.49	....	6.10	6.71	....	3.13	3.24	.28
	6-16	63	.44	.49	....	.60	.46	....	7.22	8.40	....	3.32	3.50	.27
	6-22	69	.51	.56	....	.63	.45	....	9.80	10.89	....	3.82	3.37	.25
	6-29	76	.61	.63	....	.61	.55	....	13.40	13.70	....	3.82	3.64	.34
	7-7	84	.56	.66	....	.58	.64	....	15.90	18.46	....	3.75	3.69	.42
	7-15	92	.56	.60	....	.57	.94	....	21.31	22.62	....	3.97	3.84	.55
III	7-21	98	.45	.52	....	.54	1.12	....	22.70	25.89	....	3.57	3.73	.62
	7-29	106	.36	.44	....	.49	1.26	....	28.27	32.96	....	3.29	3.46	.73
	8-4	112	.32	.37	....	.41	1.34	....	35.06	40.19	....	2.72	2.57	.80
	8-9	117	.30	....	....	.35	1.39	....	36.57	....	....	2.04	....	.83
	8-11	119	....	.32	....	.33	1.41	....	....	46.59	....	....	2.14	.85
	8-15	123	....	.33	....	....	1.46	....	....	49.04	....	....	1.75	.85

^aFlowers.

had apparently nearly reached a maximum in the last samples, whereas the stone content decreased thruout the third period.

The consistently greater amount of ash in the N flesh suggests a slightly more active assimilation as a result of the nitrogen fertilization. This may have been due to greater transpiration. Childers^{12*} has reported that the application of nitrate of soda to apple trees increased transpiration, and Freeland^{28*} found that the ash content of tomato, bean, and other plants increased with the rate of transpiration. The

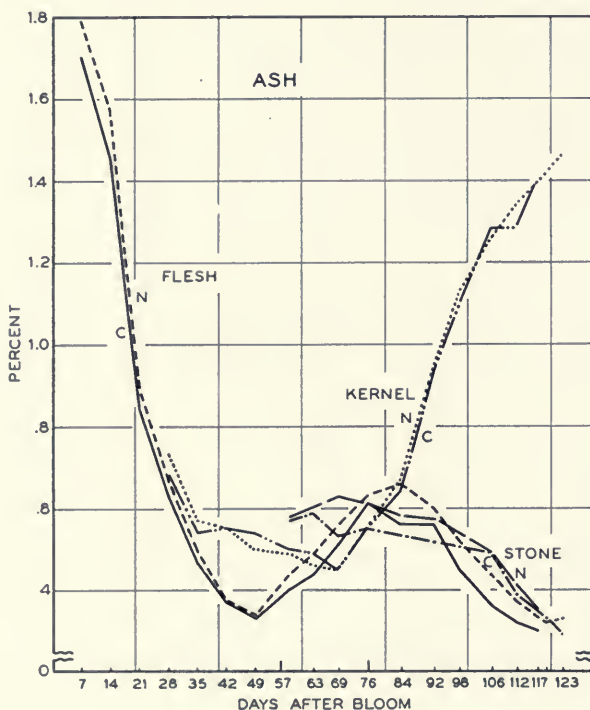


FIG. 10.—SEASONAL CHANGES IN ASH CONTENT OF FLESH, STONE, AND KERNEL ON FRESH BASIS

differences in percent were small, however, the differences in amounts being due largely to the greater mass of the N flesh, especially in the last few samples.

Nightingale^{51*} found a consistently higher percentage of ash in the flesh of high-nitrogen fruits than in the flesh of high-carbohydrate fruits and a decrease in both to or near harvest. His interpretation is somewhat surprising, viz.: "As sugars increase, the percentage of ash decreases, apparently indicating, as in the case of nitrogen, that there

is no considerable intake of the mineral elements after the early stages of fruit development." He apparently did not consider the total amount per fruit to be of importance. Actually, Table 13 shows approximately seven times as much in the flesh at maturity as at the beginning of the second period, nearly three times as much in the kernel, and over four times as much in the fruit as a whole. *The use of percentages as the basis of conclusions regarding the assimilation by the fruit of any particular constituent obviously may be very misleading unless used in conjunction with the actual amounts involved.* On the percentage basis the kernel was the only part of the fruit which showed an increased assimilation of ash during the second and third growth periods. Only in the stone did the percentage give a fairly accurate picture of the actual assimilation.

Ether extract. The outstanding feature of this constituent was the decrease in both the percentage and the amount in the kernel during the second growth period and the accelerated rate of increase in the third period, as shown in Table 14 and Fig. 11. This is in agree-

TABLE 14.—ETHER-EXTRACT CONTENT OF PEACH KERNEL

Growth period	Date collected	Days after bloom	Percent of fresh weight		Grams per 100 fruits		Percent of dry weight	
			C	N	C	N	C	N
I	5-12	28	2.49	2.71	.09	.11	17.94	22.21
	5-19	35	1.64	1.42	.17	.17	21.33	18.93
	5-26	42	.94	.99	.21	.26	13.28	14.41
	6-2	49	1.11	1.12	.47	.56	15.68	16.59
II	6-10	57	.98	.91	.56	.57	13.92	13.48
	6-16	63	.94	.90	.53	.56	13.17	13.24
	6-22	69	.87	.72	.49	.43	11.07	9.45
	6-29	76	.64	.54	.37	.33	7.09	6.18
III	7-7	84	1.22	1.13	.70	.72	9.76	9.68
	7-15	92	5.15	4.38	3.04	2.87	25.75	23.95
	7-21	98	8.27	7.19	4.85	4.66	32.30	29.12
	7-29	106	14.97	12.67	8.26	8.09	42.60	39.24
	8-4	112	16.62	16.64	10.10	10.32	43.93	41.60
	8-9	117	19.33	.....	10.75	.....	45.93	.....
	8-11	119	.....	20.16	.....	12.22	.....	45.59
	8-15	123	.....	21.89	.....	12.70	.....	46.67

ment with Hiley and Elberta in Mississippi^{40*} but not with Mayflower and Early Rose.^{42*} The decrease in amount coincided with the first macroscopic evidence of the embryo. The continued decrease until the embryo was approaching its maximum size indicates that carbohydrates which were formerly being stored as substances extractable by ether were being utilized in embryo development. Additional weight is supplied to this interpretation by the fact that sugars, and starch and dextrin in the kernel showed a decrease in amount at the start of the second period. The development of the endosperm to its maximum size during this time must not be overlooked as an additional factor in the utilization of food and nutrients.

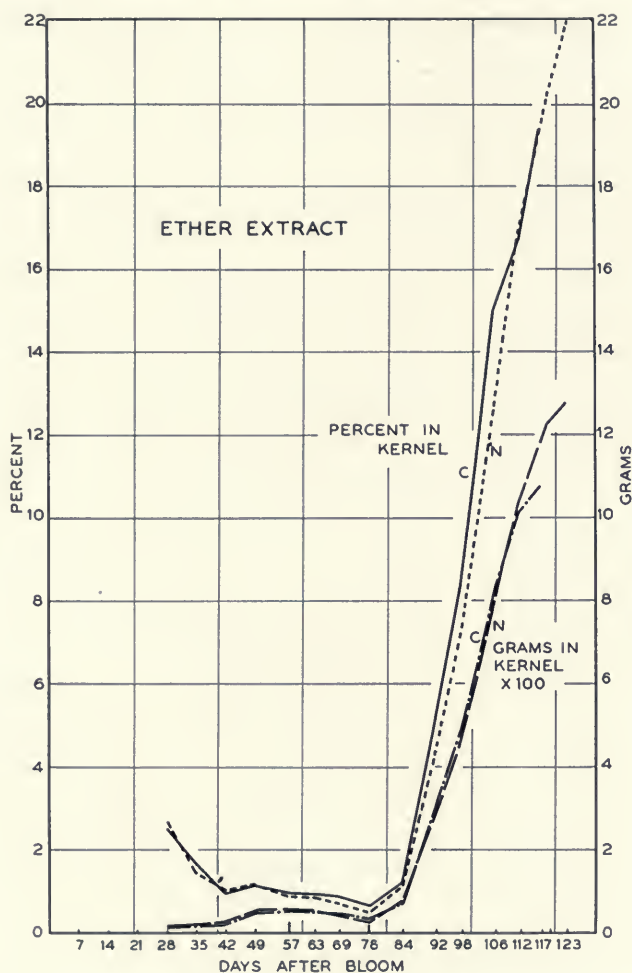


FIG. 11.—SEASONAL CHANGES IN AMOUNT AND PERCENTAGE OF ETHER EXTRACT IN PEACH KERNEL, FRESH BASIS

Effects of Nitrogen Fertilization

It should be pointed out that this investigation was different in one important respect from the usual studies of the effect of nitrogen applications. Whereas it is customary to apply nitrogen to trees of low vigor and compare results with similar unfertilized trees, in this case the trees at the start of the investigation were in a state of vigor that is usually considered to be highly satisfactory for peach production. In this investigation, therefore, the effect of the application of nitro-

TABLE 15.—COMPOSITION OF ENTIRE PEACH FRUIT
(Grams per 100 fruits)

Growth period	Date col- lected	Days after bloom	Reducing sugars		Sucrose		Starch and dextrin		Hemicellulose		Nitrogen		Ash	
			C	N	C	N	C	N	C	N	C	N	C	N
I	4-14 ^a	0	.42	.43	.07	.06	.07	.07	.41	.40	.09	.09	.02	.02
	4-21	7	.02	.02	.01	.01	.01	.01	.05	.05	.02	.02	.04	.04
	4-28	14	.07	.06	.02	.02	.03	.03	.20	.20	.06	.07	.11	.12
	5-5	21	.94	.93	.07	.07	.32	.23	1.33	1.40	.24	.26	.41	.45
	5-12	28	4.00	4.25	.23	.19	1.19	1.19	3.16	3.65	.45	.56	.70	.83
	5-19	35	10.74	11.64	.37	.53	2.28	2.23	6.25	6.85	.79	.93	1.51	1.76
	5-26	42	27.79	28.27	1.28	1.37	4.61	4.10	12.95	12.67	1.35	1.68	3.11	3.28
II	6-2	49	60.91	60.29	5.41	4.44	7.56	7.93	29.60	31.71	2.24	2.78	5.25	5.86
	6-10	57	75.95	71.82	8.38	10.91	14.82	12.38	58.99	57.76	3.26	4.16	9.51	10.25
	6-16	63	81.38	76.73	6.47	8.34	15.57	12.75	78.56	80.19	3.56	4.93	10.81	12.18
	6-22	69	95.47	88.05	6.36	8.78	19.69	15.27	113.12	114.93	4.00	6.05	13.87	14.53
	6-29	76	99.81	94.72	8.23	10.59	14.42	16.20	127.19	128.49	4.53	6.98	17.84	17.68
III	7-7	84	120.71	113.72	18.61	19.99	13.53	12.29	151.27	156.65	5.11	8.53	20.02	22.57
	7-15	92	152.92	151.02	18.77	17.37	19.19	25.32	186.71	195.05	6.19	10.52	25.83	27.08
	7-21	98	191.42	188.67	56.20	52.53	19.26	26.84	207.01	236.19	6.47	11.36	26.91	30.35
	7-29	106	312.42	275.72	132.39	127.71	30.67	34.12	254.97	268.26	6.95	12.30	32.27	37.22
	8-4	112	436.81	394.42	230.76	275.04	34.92	36.32	280.90	291.50	7.00	14.75	38.56	43.59
	8-9	117	424.61	447.92	550.80	607.13	24.15	23.26	304.13	304.13	6.32	16.29	39.38	49.48
	8-11	119	.....	439.19	.....	735.75	.....	40.96	.....	.....	.....	16.29	.....	49.48
	8-15	123	.....	.....	.....	.....	.....	36.94	.....	252.23	.....	16.54	.....	51.64

^aFlowers.

gen in the form of nitrate of soda was measured on vigorous trees in a full crop year in which there were an abundance of rainfall, slightly above normal but not excessive temperatures, and no outbreaks of disease on the trees. In the final analysis the effect of the production

TABLE 16.—HARVEST WEIGHTS AND COMPOSITION OF FRUIT OF NITRATED TREE EXPRESSED AS PERCENTAGES OF FRUIT OF CHECK TREE

Part	Volume	Fresh wt.	Dry wt.	Reducing sugars	Sucrose	Starch and dextrin	Hemicellulose	Nitrogen	Ash	Ether extract
Relative amounts per fruit										
Fruit.....	123	121	121	103	133	153	108	262	131	118
Flesh.....	123	122	126	104	134	158	109	305	134	...
Stone.....	113	104	106	84	56	123	106	114	86	...
Kernel....	104	104	116	123	84	136	117	119	110	118
Relative fresh-weight percentages										
Flesh.....				85	110	129	90	250	110	...
Stone.....				81	55	119	102	110	83	...
Kernel.....				118	80	127	112	114	105	113

of a fruit crop upon the vegetative growth and the future fruit-producing potentialities of the unfertilized tree was determined. A comparison of the physical and chemical make-up of the fertilized and nonfertilized fruit is given in Table 16.

Effects on tree. The most obvious effect of the nitrogen upon the tree was the much darker green of the leaves which prevailed thruout the season. Closer inspection showed that the leaves were larger, and the data of Table 19 show that they were heavier than on the C trees. The maximum shoot length on the C tree was 6 inches, with very few shoots over 3 inches long. The longest shoots on the fertilized tree were 12 to 15 inches, with most of the shoots under 10 inches long. There were a great many shoots less than 6 inches long on the N tree. This was apparently due to the nitrogen causing many buds to push out into short shoots. Such buds on the C tree remained dormant. The much more extensive bearing area which resulted from greater total shoot growth on the N tree and the production of more double buds at the nodes provided a larger potential crop on the fertilized tree. This was particularly noticeable when the trees were in full bloom on May 1, 1939.

Effects on fruit. The fruit set was distinctly greater on the N tree. No detailed records were obtained concerning this, but the difference was quite obvious to anyone familiar with peach fruit setting. The June drop was heavier from the C tree. As a result of this and the larger size of the fruits on the fertilized tree, the yield was greater

TABLE 17.—SUGAR CONTENT OF PEACH FRUIT EXPRESSED AS PERCENTAGE OF DRY WEIGHT

Growth period	Date collected	Days after bloom	C		N	
			Reducing sugars	Sucrose	Reducing sugars	Sucrose
Flesh						
I	4-14 ^a	0	16.20	2.85	16.83	2.52
	4-21	7	5.50	1.87	5.12	1.71
	4-28	14	4.61	1.52	4.20	1.57
	5-5	21	10.70	.79	10.57	.74
	5-12	28	19.19	.89	19.34	.55
	5-19	35	23.42	.68	23.81	.93
	5-26	42	26.56	1.17	26.74	1.21
	6-2	49	30.30	2.66	29.83	2.14
II	6-10	57	27.48	2.97	27.15	3.03
	6-16	63	28.53	2.15	27.16	2.88
	6-22	69	28.68	.95	27.43	2.20
	6-29	76	27.91	1.72	27.43	1.82
III	7-7	84	28.60	3.81	27.06	4.69
	7-15	92	27.57	3.21	27.13	3.03
	7-21	98	28.54	8.43	27.93	7.84
	7-29	106	30.19	12.90	26.82	12.56
	8-4	112	32.92	17.46	27.72	19.46
	8-9	117	27.71	36.14	.....	.....
	8-11	119	.....	.....	24.56	33.49
	8-15	123	.....	.....	22.80	38.44
Stone						
II	6-10	57	12.60	1.42	12.54	3.83
	6-16	63	6.56	.60	6.35	.71
	6-22	69	2.91	1.23	2.74	.80
	6-29	76	1.97	.65	1.68	1.21
III	7-7	84	1.30	.67	1.14	.14
	7-15	92	1.13	.27	.98	.16
	7-21	98	.98	.16	.98	.16
	7-29	106	.97	.17	.85	.13
	8-4	112	.90	.26	.70	.15
	8-9	117	.70	.27	....	....
	8-11	119	....	....	.55	.16
	8-15	123	....	....	.56	.15
Kernel						
I	5-12	28	15.19	10.22	14.75	12.79
	5-19	35	13.39	8.19	12.93	9.33
	5-26	42	10.59	4.38	10.48	4.66
	6-2	49	10.03	2.82	10.52	4.45
II	6-10	57	9.09	4.26	8.30	4.44
	6-16	63	8.82	3.64	7.94	3.97
	6-22	69	8.65	3.31	7.35	3.02
	6-29	76	9.63	6.09	8.35	7.78
III	7-7	84	7.44	8.00	6.34	8.40
	7-15	92	8.45	3.80	8.37	2.90
	7-21	98	6.17	3.28	6.24	2.79
	7-29	106	4.30	2.22	4.74	2.35
	8-4	112	4.36	2.62	4.65	2.45
	8-9	117	4.24	4.87	....	....
	8-11	119	....	....	4.50	2.69
	8-15	123	....	....	4.48	3.52

^aFlowers.

on the fertilized tree than on the check tree. This was not recorded in detail because of the constant removal of fruits in sampling during the season, but there was an obvious difference.

TABLE 18.—STARCH AND DEXTRIN, HEMICELLULOSE, NITROGEN, AND ASH CONTENTS OF PEACH FRUIT
EXPRESSED AS PERCENTAGES OF DRY WEIGHT

Growth period	Date col- lected	Days after bloom	Flesh		Stone		Kernel		Flesh		Stone		Kernel				
			C	N	C	N	C	N	C	N	C	N	C	N			
I	4-14 ^a 4-21 4-28 5-5 5-12 5-19 5-26 6-2	0 7 14 21 28 35 42 49	Starch and dextrin														
			2.60	2.73	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....			
			2.20	2.37	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....			
			1.98	1.98	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....			
			3.66	2.61	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....			
			5.19	4.90	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....			
			4.70	4.28	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....			
			4.28	3.72	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....			
			6-2	3.64	3.78	.....	.....	.....	.....	.....	.....	.....	.....	.....			
			II	6-10 6-16 6-22 6-29	57 63 69 76	Starch and dextrin											
5.47	4.91	1.96				1.41	8.95	10.22	14.72	14.51	23.63	23.62	11.07	10.37			
5.18	4.32	1.53				1.15	6.72	7.79	14.87	14.77	24.04	24.10	11.07	10.37			
5.24	4.39	1.30				0.78	5.34	6.04	15.10	15.58	24.62	24.81	11.20	10.37			
2.91	3.92	1.30				0.90	7.09	7.32	15.41	15.20	22.36	22.27	12.40	13.16			
III	7-7 7-15 7-21 7-29 8-4 8-9 8-11 8-15	84 92 98 106 112 117 119 123				Starch and dextrin											
						2.26	2.03	1.00	0.84	6.16	6.60	12.64	13.36	24.80	23.36	11.04	11.48
						2.57	3.74	1.14	0.98	3.35	3.94	14.21	13.88	24.73	24.20	7.70	8.37
						2.32	3.27	0.85	0.98	2.42	2.79	12.84	12.56	27.40	30.20	7.11	7.53
						2.55	2.90	0.97	0.89	1.29	1.89	11.12	11.52	30.44	29.80	6.35	6.53
			2.32	2.32	0.85	0.70	1.21	1.55	11.11	10.73	28.65	28.95	6.11	6.25			
			8-9	1.37	0.73	1.21	.....	.....	.....	.....	.....	.....	.....	.....			
			8-11	2.01	0.85	.....	.....	.....	.....	.....	.....	.....	.....	.....			
			8-15	1.71	0.85	.....	.....	.....	.....	.....	.....	.....	.....	.....			
			I	4-14 ^a 4-21 4-28 5-5 5-12 5-19 5-26 6-2	0 7 14 21 28 35 42 49	Nitrogen											
3.49	3.44	.....				.....	.....	.....	.....	.....	.....	.....	.....	.....			
5.50	5.67	.....				.....	.....	.....	.....	.....	.....	.....	.....	.....			
4.20	4.41	.....				.....	.....	.....	.....	.....	.....	.....	.....	.....			
2.76	2.90	.....				.....	.....	.....	.....	.....	.....	.....	.....	.....			
2.15	2.42	.....				.....	.....	.....	.....	.....	.....	.....	.....	.....			
1.70	1.85	.....				.....	.....	.....	.....	.....	.....	.....	.....	.....			
5-26	42	1.25				1.53	.....	.....	.....	.....	.....	.....	.....	.....			
6-2	49	1.06				1.31	.....	.....	.....	.....	.....	.....	.....	.....			
II	6-10 6-16 6-22 6-29	57 63 69 76				Nitrogen											
			0.95	1.30	0.91	1.11	3.69	4.15	2.70	3.18	2.92	2.87	7.10	7.26			
			0.87	1.30	0.71	0.90	3.92	4.26	2.96	3.53	1.91	1.89	6.86	6.76			
			0.71	1.33	0.56	0.71	3.94	4.07	3.22	3.73	1.41	1.21	5.91	5.14			
			0.86	1.49	0.43	0.54	4.65	4.92	4.03	4.26	1.13	1.03	6.09	6.29			
			III	7-7 7-15 7-21 7-29 8-4 8-9 8-11 8-15	84 92 98 106 112 117 119 123	Nitrogen											
						0.85	1.61	0.34	0.40	4.72	4.88	3.95	4.62	0.93	0.84	5.12	5.74
						0.86	1.62	0.23	0.25	4.80	4.98	4.00	4.23	0.89	0.78	4.70	5.14
						0.77	1.45	0.16	0.17	4.65	5.02	3.48	3.96	0.80	0.74	4.30	4.54
						0.54	1.04	0.15	0.17	4.01	4.65	2.78	3.27	0.68	0.68	3.64	3.90
0.42	0.93	0.14				0.15	3.73	4.03	2.67	2.86	0.58	0.54	3.38	3.35			
8-9	0.32	0.14						3.66		2.41	0.47			3.30			
8-11	0.81	0.15						3.78		2.58	0.44			3.19			
8-15	0.78	0.15						3.73		2.57	0.38			3.11			
I	4-14 ^a 4-21 4-28 5-5 5-12 5-19 5-26 6-2	0 7 14 21 28 35 42 49				Hemicellulose											
			15.88	15.89	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....			
			12.32	13.42	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....			
			13.53	13.37	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....			
			15.21	15.85	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....			
			14.94	16.47	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....			
			13.55	13.90	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....			
			12.31	11.87	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....			
			14.65	15.61	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....			
			II	6-10 6-16 6-22 6-29	57 63 69 76	Hemicellulose											
14.72	14.51	23.63				23.62	11.07	10.37									
14.87	14.77	24.04				24.10	11.07	10.37									
15.10	15.58	24.62				24.81	11.20	10.37									
15.41	15.20	22.36				22.27	12.40	13.16									
III	7-7 7-15 7-21 7-29 8-4 8-9 8-11 8-15	84 92 98 106 112 117 119 123				Hemicellulose											
						12.64	13.36	24.80	23.36	11.04	11.48						
						14.21	13.88	24.73	24.20	7.70	8.37						
						12.84	12.56	27.40	30.20	7.11	7.53						
						11.12	11.52	30.44	29.80	6.35	6.53						
			11.11	10.73	28.65	28.95	6.11	6.25									
			8-9	8.51	24.11	24.11	5.89	.....									
			8-11	9.34	27.71	27.71	5.97	.....									
			8-15	7.39	23.95	23.95	5.91	5.91									

^aFlowers.

TABLE 19.—LEAF DEVELOPMENT IN TWO PEACH TREES

Date collected	Days after bloom	Fresh weight per leaf		Dry weight per leaf		Percent dry matter		Dry weight of leaves per inch of shoot	
		C	N	C	N	C	N	C	N
		grams	grams	grams	grams			grams	grams
5-24	40	.2974	.3372	.0965	.1040	32.45	30.86	.5167	.3962
6-8	55	.4295	.5293	.1597	.1884	37.18	35.59	.5287	.4300
7-1	78	.4997	.6247	.1945	.2575	38.92	41.22	.7873	.4993
7-14	91	.3509	.7038	.1460	.2703	41.61	38.41	.7567	.4891
8-16	124	.3861	.8475	.1641	.3314	42.50	39.10	.8218	.6026
10-11	180	.4230	.7255	.2055	.3780	48.58	52.10	.....	.....

The nitrogen fertilization resulted in greater breadth of the fruit in comparison with length, as shown by the relative diameters at maturity, which were: C fruits—polar diameter 100, suture diameter 104, cheek diameter 101; N fruits—polar diameter 100, suture diameter 110, cheek diameter 107. Blake *et al*^{6*} also reported this effect from nitrogen on the development of Elberta.

The frequently reported reduction of fruit color from nitrogen fertilization was not an important factor. The red color of the nitrated fruits was less intense but no less attractive than that of the check fruits. The Halehaven variety is almost entirely overspread with red when ripe and the ground color is orange-yellow; hence any effect on color would be less noticeable than on varieties with a lighter yellow ground color and relatively little overlying red. The check fruits had considerably more red color in the flesh than the N fruits. This might be objectionable to some consumers. A high carbohydrate condition might easily be developed in which objectionable quantities of cellulose, lignin, and tannins would occur. This would be much more undesirable than any effect usually secured from the intelligent use of nitrogen fertilizers. Persons unfamiliar with the treatments could not detect any difference in quality between the two lots of fruit.

The later ripening of the fertilized fruits was due to the establishment of a growth status that caused the flesh of these fruits to increase in size and dry matter longer than the flesh of the check fruits (Table 3).

Altho the N fruits had larger and heavier stones, the percent of the fruit that was flesh was also slightly greater, whether measured on the fresh-weight or the dry-weight basis, than in the C fruits (Table 8).

The greater dry weight and larger amounts of all determined constituents except sucrose in the kernels from the fertilized fruits than in the kernels from the check fruits shows that the application of nitrogen resulted in a more efficient or higher metabolic rate in the kernels or in other parts of the tree from which elaborated foods were translocated to the kernel for storage. Proebsting^{55*} reported that

nitrogen applications to Nonpareil almonds increased the kernel weight 41 percent.

The above discussion concerning the effects obtained from the use of supplemental nitrogen in the form of nitrate of soda shows that the desirable effects exceeded by far the small cost involved. Furthermore it is quite probable that essentially the same effects would have been secured from the use of considerably less fertilizer, since the amount applied was purposely large in order to insure a difference in vigor between the trees of the two treatments. The later ripening of the nitrated fruits was not as important as it would be with an early ripening sort. The increase in yield would in most cases offset a possibly higher market price in the early ripening unnitrated fruits in the Halehaven variety.

APPLICATION OF RESULTS

The presence of relatively large quantities of all the fruit constituents in the peach flowers indicates the need for a considerable reserve of these constituents in the tree when growth starts in the spring. A tree of the size and vigor of those used in this investigation might easily have 10,000 flowers. The dry weight of the flowers from the check trees was .0260 gram per flower. On this basis the total dry weight of the flowers on the trees would be 260 grams, or the equivalent of 13 mature fruits. This seems small in comparison with the mature crop, but it must be remembered that the initiation of shoot and leaf development at this time, as well as growth in the older parts of the tree, provides competition with the flowers for food and nutrients. While there may be some absorption of these materials from the flower before petal and shuck fall, as Howlett^{34*} and Murneek^{48*} have reported for the apple, nevertheless they must be present before normal flower development can occur. That a considerable part of the substances in the flower were not translocated into the fruit or shoots is shown by the fact that the dry weight of the abscised shucks was nearly 65 percent of that of the flower. A further temporary loss would be the dry weight of the fallen petals. This was not determined.

The rapid increase in the dry weight of the fruit during the first growth period emphasizes further the need for adequate storage in the dormant tree of materials utilizable in growth. Altho the dry weight per fruit was never large during the period, the large number of fruits present until the drops were completed and the competition from vegetative growth in the tree would require an abundance of food and nutrients.

The greater set of fruit on the nitrated tree shows the need for nitrogen at this time. This would be particularly important in seasons in which a large percent of the buds were killed by low temperatures.

The continued increase in dry matter during the second growth period shows that there is a far greater need during this period for food and nutrients for the growing fruit than is indicated by the increase in the size of the fruit. The increase in the dry weight of the fruit during the second period (Table 3) was as great as the increase in the first growth period even tho the time interval was only one-third as great. It is important to the grower to know that even tho the fruit may be increasing very little in size during this period, its developmental needs are undiminished.

The very rapid development of the fruit during the third growth period emphasizes the need for the use of cultural practices which provide an extensive leaf surface, the functioning of which is not restricted by disease or insect injury. The need for the maintenance of an adequate supply of soil moisture is also obvious.

The very significant influx of sugars during the last week of the season shows very definitely the desirability of allowing the fruit to approach the soft ripe condition as nearly as is consistent with necessary handling in picking, packing, and transportation. Not only is the quality enhanced, but there is also a significant improvement in food value. Furthermore the flesh-stone ratio increases (Table 8). Dorsey and McMunn^{22*} have pointed out the significant increase in fruit volume during the usual harvesting period and the possibility of delaying harvest as much as seven days without increased transit and storage losses. Growers can well afford to take advantage of the increased size and quality which results from delayed harvesting. Some growers are afraid that heavy fruit drop may result from such delayed harvesting. The possibility of the so-called "hormone" sprays being effective in reducing or largely preventing such drop merits detailed investigation.

There has been a great deal of discussion in the literature on the relation of fruit growth to the time of fruit thinning. The primary object of thinning is to increase size and grade without decreasing yield. Thinning reduces competition between fruits and thus encourages larger fruits or greater storage of foods in the vegetative portions of the tree, or both. The question therefore is when to thin to obtain the greatest relief from competition between fruits.

Since the fruit continues to increase rapidly in size until it is nearly ripe, it would seem that thinning might be extended to within a few weeks before harvest and still cause an increase in size of fruit because it would reduce the competition between fruits for food. Dorsey and McMunn^{23*} have reported that this occurred in a study of late thinning. They point out that when growth conditions during the first period are especially unfavorable, it would seem desirable to delay thinning until the second period if a post-June drop seemed likely. Since their investigation was conducted for only one year, the effect on the storage of materials in the tree was not measured.

Shoemaker^{59*} compared early thinning done just before or soon

after the June drop with late thinning done approximately a month later. He found that early thinning was most profitable. In the second year of the study the trees thinned early produced twice as much as those thinned late, and the profits were twice as great. This shows the need for consideration of the cumulative effect from thinning. When intervening crops are killed by frost, however, there might be little cumulative effect.

The most recent work on this subject is that of Tukey and Einset,^{70*} who thinned at five dates extending from full bloom until the middle of the third growth period in each of three seasons, and drew the following conclusions:

"The most effective time of thinning so far as good size and color of fruit is concerned, coupled with the least reduction in yield, was secured from thinning early in stage I. Blossom thinning, too, was effective but the removal of blossoms without injury to those remaining made the method somewhat uncertain. Thinning at the end of stage I, middle of stage II, or middle of stage III gave results somewhat similar to each other, and which were intermediate between those from no thinning and from thinning early in stage I."

These investigators also found that blossom thinning and thinning early in the first period gave more blossoms the following year. They reported that the size of the stone in individual fruits was greater from the trees thinned early than from the unthinned trees. They say, "Early thinning may thus result in larger fruit because of an effect upon the size and development of the stony pericarp as well as upon the fleshy pericarp." Dorsey and McMunn^{20*} did not find an increase in size of stone from early thinning. They report, however,^{20, 21*} that the larger fruits in Elberta tend to have the larger stones.

The information cited above indicates that, in general, early thinning has resulted in more profitable crops and a greater storage of food in the trees than late thinning. While the results of Tukey and Einset show that thinning before the normal drops were over was most desirable, many growers would probably hesitate to thin before the June drop was completed. Detailed investigation of the effect of very early thinning upon the extent of the June drop seems desirable.

The data of this and other investigations^{30, 40*} indicate that thinning before the stone hardens would conserve a large quantity of carbohydrates that otherwise would be utilized in the rapidly increasing dry matter in the stone in the second period. It would seem a waste of materials, therefore, to allow stone hardening to occur before thinning. While the disadvantage might not be evident during the first season, the effect might well become an accumulative factor of considerable importance over a term of years.

The increased fruit size obtained by the use of nitrogen shows the necessity for adequate available quantities of this element. The resulting increase in size and yield would probably offset any decrease in market price due to later ripening in a variety of the ripening season

of Halehaven. The advantage or disadvantage to a grower would depend on his local conditions.

Of equal or greater importance than the difference in yield and fruit size was the effect of the nitrogen on the vegetative vigor of the tree. Not only did it give larger fruit but it also provided an abundance of fruit buds, thus insuring a satisfactory potential crop for the following year. That this was due to greater photosynthetic activity of the leaves of the fertilized tree is indicated by the work of Childers,^{12*} who found a higher rate of photosynthesis in apple leaves on nitrogen-fertilized trees. It is quite probable that the discovery of Pickett^{53, 54*} that there is a difference in the photosynthetic rate in apple varieties which is correlated with the difference in the extent to which the leaf cells come in contact with the air might be applicable here, since it is well known that there is a structural difference in leaves that differ in vigor to the extent that the leaves in this investigation did.

Altho the greater dry weight and greater amounts of all determined constituents except sucrose in the nitrated kernels at harvest may not be of importance to the grower, it may be of considerable value to the peach breeder. Connors^{13*} first pointed out that the early-ripening peach varieties Mayflower, Early Wheeler, and Greensboro failed to produce viable seed (mature ovules). This condition has also been mentioned by Chandler^{10*} in Sneed. Sakaguti^{57*} broadened the viewpoint on this subject somewhat by the statement that kernels which failed to develop 10 percent of dry matter were nonviable, and that varieties producing such kernels should therefore be avoided as female parents in breeding. He recommended that varieties ripening in less than 100 days after bloom be avoided as female parents, apparently on the assumption that this length of time is necessary to develop 10 percent of dry matter in the kernel. Lott and Ashley,^{41*} however, showed that altho there was a progressive increase in dry weight in the kernel as the interval from bloom to maturity increased, the variety Early Rose reached a dry-matter percentage of 15.45 in 85 days after bloom and Carman reached 30.29 in 102 days after bloom. Furthermore, a number of seedlings in the University of Illinois peach-breeding plots reached a kernel dry-matter percentage of 25 to 35 in approximately 100 days after bloom in 1941.

The desirability of ascertaining the dry weight and the dry-matter percentage of the kernels of each variety at harvest would seem clear from the foregoing evidence. The low dry weight of these Halehaven kernels compared with those of Hiley, ripening in the same number of days after bloom^{40*} (.234 gram in Halehaven and .352 in Hiley), further emphasizes this point and also suggests that Halehaven may not be a particularly good variety to use as a female parent. Consequently the significant increase in the dry weight of the kernel shown

in Table 4 as the result of nitrogen fertilization may be very important. The relation of the dry weight of the kernel to the vigor of the resulting seedling must be determined in order to make this information of practical value; this is a phase of peach breeding that merits investigation. The increase in dry weight and stored materials in the kernel as a result of nitrogen fertilization may make the difference between good and poor or no germination. The artificial culture methods of Tukey^{66, 68*} and of Davidson^{15, 16*} could be used in the non-nitrated kernels, but the relatively simple and inexpensive method of applying nitrogen fertilizer would be much more preferable where effective. The greatest use of this method would be with those varieties on the borderline between having and not having sufficient stored food in the kernels for satisfactory germination. Halehaven may be in this group. In this connection there is the possibility of source of pollen being an important factor in the development of the fruit, as has been shown in dates,^{14*} and the possibility of this effect extending to the kernel and perhaps being influenced by the nitrogen supply.

The often mentioned possibility that the application of nitrogen fertilizers might result in fruit of inferior color and quality did not occur in this test. In fact, all of the effects obtained from the use of fertilizer, with the possible exception of a lower market price due to the fruit ripening later on the fertilized tree, were highly desirable. Consequently the conclusion is inevitable that, under conditions similar to those of this investigation, the use of a liberal quantity of a readily available nitrogenous fertilizer is highly desirable, as it results in more vigorous vegetative growth, the formation of more fruit buds, and a greater yield of larger fruit as attractive in color and as high in quality as that from nonfertilized trees.

NATURE OF GROWTH PERIODS

It seems desirable at this point to consider the nature of the three periods of size increase in the peach fruit, with the object of reaching a more comprehensive understanding of them.

First Growth Period

It was reported by Addoms^{1*} that cell division in the young Elberta peach was very rapid following fertilization and that it had practically ceased by the thirtieth day after bloom. She concluded that increase in size thereafter was effected principally by the enlargement of the cells already formed. The data of Tables 3 and 15 show that there was an extremely rapid rise in size and dry weight, and in all determined chemical constituents soon after fertilization, if it is assumed that fertilization occurred 12 to 14 days after bloom, as has been reported.^{57*} The data of Connors^{13*} also show an accelerated rate of

size increase beginning about 12 days after bloom. According to the hypothesis of Gustafson,^{29, 30, 31*} this acceleration in growth following fertilization in seed-bearing fruits may be explained thus:

"We may then think of the usual fruit growth as being initiated by pollination and fertilization, which brings into the ovary a sufficient quantity of auxin from the pollen grains and pollen tubes to start the enlargement of the ovary, and continued by the additional auxin produced by the developing embryos and seeds, which diffuses into the ovary to supply what is needed."

Considering this rapid increase in growth immediately following fertilization, it would seem that the first growth period really starts with fertilization. Since, however, the exact time of fertilization is not easy to determine and probably varies with variety, season, and location, it is usually more satisfactory to consider the time of full bloom as the starting point of the first period.

During the first period the flesh, stone, and kernel increased rapidly in size and in fresh and dry weights (Table 4). The relatively high percent of dry matter in the fruit in the first four weeks of this period (Table 7) may be associated with the hydrion concentration, as pointed out by Caldwell,^{9*} who studied a number of common fruits, including the cherry but not the peach, and found that the young fruits at setting and for a short period thereafter had a low hydrion concentration and a high solids content. During this time rapid and general cell division occurred.

Caldwell continues with the statement that this period was followed by one of rapid increase in active acidity, rapid water absorption, and the most rapid percentage increase in weight and volume of the fruit. The latter period of activity would coincide with the last few weeks of the first growth period of the fruit. Consequently the assumption seems valid that the flesh, stone, and kernel of the peach fruit develop after bloom and fertilization in the manner characteristic of developing tissues in general; that is, during the first growth period they undergo a period of cell division which is followed by rapid cell enlargement.

Second Growth Period

The possible reason for the occurrence of this period of retarded rate of size increase has received considerable attention from investigators. During this period the flesh, stone, and kernel apparently continue in what is usually considered to be the normal fashion for size increase of an organ; that is, after having passed thru the stages of cell division and rapid cell enlargement during the first growth period, they evidence a slower rate of size increase coincident with cell differentiation. This differentiation is characterized by increased thickness of cell walls in the flesh, increased thickness and lignification in the walls of the stone cells, increased thickness in the cell walls of the integuments, and the chemical changes already discussed.

In this work both the stone and kernel had reached nearly maximum volume at the beginning of the second period (Table 4). This fact, coupled with the rapid hardening of the stone in the first part of the period, making further enlargement difficult, shows that any retarded rate of size increase must occur largely in the flesh. Significant increase in flesh volume occurred during this period but there was some retardation in the rate of increase (Tables 4, 5 and 6).

The fact that the rate of dry-matter accumulation in the fruit as a whole continued to increase, and that this was the case in previous investigations,^{39, 40*} shows that whatever the cause for the retarded rate of size increase in the flesh it is within the fruit itself and is not due to such external factors as competition from shoot development, as has been suggested.^{19*}

The question naturally arises whether wall thickening and other changes in the flesh cells can account for the retarded rate of size increase in the flesh. Information is needed on the histological behavior, during this period, of different varieties during different seasons of ripening before this question can be entirely answered. However, the chemical data may partly explain the developmental activity of the flesh at this time. The rate of accumulation of reducing sugars in the flesh at the beginning of the second period was appreciably slower than before or after this time, while the amount of sucrose actually decreased (Table 9). Apparently the sugar changed to more complex carbohydrates in the flesh or was used elsewhere in the fruit. Hemicellulose increased very rapidly in the flesh from the 49th to 57th day, the amount on the 57th day being approximately equal to that of flesh and stone combined on the 49th day (Table 11). The rate of accumulation of hemicellulose in the flesh was somewhat slower thereafter and may not have been great enough to account for the low rate of accumulation of sugars during the remainder of the period. The increase in the starch and dextrin content during this time was not enough to be of any importance in this connection (Table 10).

Altho the time of increase in cell-wall thickness in the flesh coincided with the increase in the amounts of hemicellulose and dry weight, the rate of accumulation of dry matter in the flesh decreased after the 57th day (Table 6) rather than increasing at a consistent rate, as might have been expected. It therefore appears that the sugars were being used more rapidly elsewhere than in the flesh after the 57th day.

Turning now to the possibility of competition from other parts of the fruit, let us consider the development of the stone.

The amount of dry matter in the stone increased rapidly during the second period and slowly thereafter, decreasing during the latter part of the final swell (Table 4). This previously was found to occur in Hiley and Elberta.^{39, 40*} The same trend is shown in Lilleland's apri-

cot data.^{36*} Coincident with this accumulation in dry matter was the rapid increase in the amount of hemicellulose (Table 11) and the lignification of the stone. The formation of these complex carbohydrates—hemicellulose and lignin—would require considerable quantities of simple sugars. Since the rate of accumulation of both sugars and total dry matter in the flesh was low after the 57th day, the stone would appear to be the dominant part of the fruit during the second period. The fact that the stone constituted over 50 percent of the dry weight of the fruit for approximately two weeks during this growth period is substantiative evidence of the flesh-stone relationship (Table 8). The same condition was shown to prevail in Hiley and Elberta^{39, 40*} and in the apricot.^{36*}

In some preliminary work with the early varieties Mayflower and Sneed in Mississippi,^{42*} it was found that the stones were not completely hard at harvest, and that the dry weight of the stone did not equal that of the flesh at any time during the season. In these early varieties the stone and flesh developed together to harvest, and the dry weight of the stone never became great enough to cause more than a short second period, or none at all, as Lilleland^{37*} found in Sneed and which also occurred elsewhere.^{42*} The concomitant development of the flesh and stone until maturity may partly account for the poor quality of these early varieties. The continued utilization of sugars by the stone would limit the amount available to the flesh. The data of Lott and Ashley^{41*} show that the sugar content of the ripe flesh increased directly in proportion to the lateness of maturity of the variety. While quality is not determined by sugar content alone, it seems to be directly associated with it. It is possible, however, for early-ripening varieties to have high sugar content, as shown by some of the seedlings from the University of Illinois peach breeding plots. The fruit of some varieties ripening approximately 100 days after bloom in 1941 had as high sugar content as late-ripening sorts such as Elberta; but the seasonal development of these fruits was not followed, nor were the flesh-stone, sugar-hemicellulose relationships investigated.

The conclusion seems plausible that the delayed rate of size increase in the flesh in the second period is due largely to a combination of cell-wall thickening with accompanying hemicellulose accumulation in the flesh, and lignification and hemicellulose accumulation in the stone. The relative dominance of these two phenomena will depend upon the genetic make-up of the variety. The part played by the rapid size increase of the endosperm and cotyledons at this time is very difficult to determine but may be of considerable importance.

Third Growth Period

One of the most striking features of peach fruit development is the rapid increase in size and dry weight during the third growth period.

It has been shown that the stone decreased slightly in size during this time. The size increase which occurred was therefore in the flesh. The increase in dry weight was also in the flesh, because the decreasing dry weight of the stone offset the dry-weight increase in the kernel. The data already presented show that the increased dry weight of the flesh was due primarily to the rapid increase in sugars. Consequently any consideration of the reason for this final swell centers largely upon the source of supply of the sugars during this period.

That there is a very noticeable increase in size during this time has been mentioned by nearly all investigators of the subject (see References 2, 5, 6, 13, 18, 22, and others), but no attention seems to have been given to any aspect other than observable size increase. A further consideration seems desirable.

It is commonly known that the volume of the flesh increases two to four or more times during this period, but there does not seem to be any definite information concerning the percentage of this increase that is due to cell enlargement and the percentage due to increase in volume of intercellular spaces. That the increase in volume is due primarily to cell enlargement is indicated by the report of Addoms^{1*} that the intercellular spaces between the flesh cells of Elberta remained relatively small during the maturation of the fruit. That there may be considerable difference between peach varieties in this respect is indicated by the fact that in some varieties of the sour cherry there are no intercellular spaces in the flesh at maturity.^{25, 71*}

The greater part of the increase in flesh volume during the third period would thus seem to be due to increase in cell size. Such increases would be accompanied by large increases in the surface area of the individual cells, which would necessitate a decrease in cell-wall thickness or a rapid increase in the deposition of cell-wall materials. It is therefore obvious that very erroneous conclusions might be reached concerning the trend of a cell-wall constituent if only the change in thickness was considered. Definite data on this point are necessary before the final swell of the peach fruit can be thoroly understood.

The next point to consider is the possibility of the transformation of more complex carbohydrates in the flesh to sugar during the third growth period. That the quantity of starch and dextrin was never great enough to be of any consequence in this respect is shown by the data in Table 10. Hemicellulose showed (Table 11) a decrease only in the last sample, and this decrease was not great enough to be of any significance in relation to the increase in the amount of sugar. Furthermore there is no assurance that any of this hemicellulose was hydrolyzed to sugar. The data of Mrak *et al*^{43*} show a fairly high percentage of lignin in dried prunes. The same condition may occur in peaches, since positive microchemical tests for lignin were obtained in the vascular bundles in the last few samples. Some hemicellulose may

have been converted to lignin; but according to the view of Ehrlich,^{26*} the lignin would more likely arise from pectin, but hemicellulose as here determined would include at least a part of the pectin.

The relationships of the more complex carbohydrates in the peach during ripening is somewhat unsettled. Nightingale^{51*} reported a decrease in protopectin, hemicellulose, and cellulose during the ripening of the peach. Since he presented the data only on the percentage basis, it is impossible to determine whether the actual amounts decreased. If, however, one assumes that the normal final swell occurred in the fruits which he examined, his data indicate that there was no decrease in amounts, with the exception of protopectin in the last sample. Appleman and Conrad^{3*} concluded that the transformation of protopectin to soluble pectin was the chief process responsible for the softening of peaches.

Obviously there is need for further study of the ripening processes, including a consideration of the cell-wall changes, and the expression of results in amounts per fruit. The conclusion seems inevitable that the large increases in sugar in the third growth period of the flesh of the peach cannot come from other forms of carbohydrates in the flesh.

The decrease in the amount of hemicellulose in the stone during the time that the sugar content of the flesh was increasing most rapidly indicates hydrolysis and translocation, since all the other analyzed carbohydrates in the stone decreased at this time. Some of the hemicellulose may have been transferred to the kernel for storage, but only a small part of the decrease could be accounted for by increases in the kernel. The amount of the decrease of hemicellulose in the stone was small in comparison with the sugar increase in the flesh, but it may have been the source of a part of the sugars. This condition might be interpreted as a hemicellulose-sugar relationship in accordance with Murneek's conception of hemicellulose as a storage carbohydrate.^{47*} Definite conclusions on this subject cannot be drawn without a more detailed separation of the acid hydrolyzable fraction here designated as hemicellulose. Nevertheless it appears that a portion of the materials included in the hemicellulose determination did act as a reserve substance that was translocated from the stone during the final swell. This condition also occurred in Hiley and Elberta.^{39, 40*} The fact that hemicellulose did not seem to act as a reserve substance in the flesh does not preclude the possibility of such a situation in the stone. Aside from the relative activity of these two organs during the third growth period, the probable difference in the nature of their hemicelluloses may play a part. According to Buston,^{8*}

" . . . lignified tissues are characterized by the presence of xylan and allied hexo-pentosans of the same series (glucosan-glycuronic anhydride-xylan), while in nonlignified material galacto-arabans constitute the main bulk of the hemicelluloses."

Because the decrease in hemicellulose in the stone could at the most account for only a small part of the sugar increase in the flesh during the final swell, and the added fact that in some early-ripening varieties the hemicellulose content of the stone has been found to increase until flesh maturity,^{42*} most of the sugar must come from the tree. Davis^{17*} found that in the Sugar prune the increase in sugars during the final swell was accompanied by a corresponding depletion of starch in the branches back of the spur. This phase of the problem has not been investigated in detail in the peach. Tottigham^{65*} considers that hemicellulose is a reserve material in the peach, but his results would not necessarily be applicable here since he did not state whether he used bearing trees.

The fact that during the third period the C leaves decreased in dry weight (Table 19) suggests the possibility that not only were all the products of photosynthesis being translocated into the fruit but some of the materials that had been temporarily stored in the leaves were also being translocated. That such a condition would be more marked in trees with a nitrogen deficiency is indicated by the fact that the N leaves did not similarly decrease in dry weight. The increased chlorophyll content from nitrogen fertilization and the greater size of the N leaves apparently made possible a rate of carbohydrate manufacture in excess of the assimilable demands of the developing fruits.

In studying the effect of fruit production on tree growth in several fruit species, including the peach, Chandler^{11*} points out the possibility of a greater rate of photosynthesis on the bearing trees, due to the removal of the products of photosynthesis to the fruit. This suggests the possibility of a greater rate of photosynthesis during the final swell because of the rapid removal of the products of photosynthesis to the fruit.

Obviously the information is too meager to permit definite conclusions concerning the cause of the rapid increase in sugars during the final swell. A more complete chemical study, more detailed investigation concerning the relationship between fruit development and the growth of all parts of the tree, and a study of the relationship between fruit growth and leaf activity are suggested as sources of additional information.

The effect of the kernel upon the growth of the flesh and stone should not be overlooked. Even tho the kernel is not important on a mass basis, it may nevertheless play a very important part in the development of the stone and flesh. It has been definitely established that the act of fertilization in some way causes a rapid rise in the growth rate.^{45, 49, 50*} It has been shown by Tukey^{69*} that in the *Prunus* species the side of the fruit to which the functional ovule is attached develops more rapidly than the other, resulting in an asymmetric fruit. When both ovules developed, the fruit was symmetrical. It is well

known that fertilization is usually necessary for normal fruit development in the common deciduous tree fruits.

The question of the possible effect upon fruit development of the growth of the kernel after fertilization is unsettled. In a study of the effect of branch ringing and defoliation on the development of the embryo of the peach,^{72*} Tukey concluded:

"... it is abortion of the embryo which induces early-ripening of the fruit, and not the reverse . . . when the supply of materials to the embryo from outside the fruit is limited, as by ringing and defoliation, the embryo continues to increase in size and storage materials continue to be mobilized."

It was found by Lott and Ashley^{41, 42*} in Mississippi that the early peach varieties Mayflower, Sneed, and Early Rose did not produce truly abortive ovules except in a small percentage of the fruits. The kernels were still plump at harvest, but the cotyledons had reached only about half the length of the nucellus. A number of seedlings in the University of Illinois peach-breeding plots which ripened fruit in approximately 100 days after bloom in 1941 had kernels in which the cotyledons filled the integuments except for a very thin layer of endosperm, and the outer integument was light brown, indicating an approach to maturity. Consequently there would seem to be no definite cause-and-effect relationship between kernel development and the initiation of the third growth period in early-ripening varieties of the peach. Furthermore there is considerable evidence to indicate that in the peach the development of the kernels to maturity is not necessary for the production of normal fruits. Havis^{33*} has recently reported the effects on peach fruit development of the death of the ovules as the result of frost three weeks after bloom. He found that the fruits with dead ovules developed in essentially the same manner as those with normal ovules. The writer has frequently observed peach fruits with aborted ovules in which the development of flesh and stone was approximately the same as that of fruits with normal ovules.

If the kernel does affect the development of the flesh, this effect probably occurs during the first three or four weeks after bloom. It is quite possible that a metabolic status that would extend to maturity could be established in the fruit during that time. This could occur on the basis of auxin brought into the ovule in the pollen tubes and that produced by the developing embryo, as conceived by Gustafson.^{31*}

Another viewpoint that might be entertained is that either or both the kind or amount of growth-regulating material is such in late-ripening varieties that the kernel is dominant over the flesh until sufficient time has elapsed to make possible the subsequent normal development of the kernel; whereas the setup in early varieties is such that the flesh dominates the kernel, with the result that the flesh completes its development while the kernel is still in a relatively undeveloped condi-

tion. A further possibility seems to be the presence, in different proportions in different varieties, of separate growth-regulating substances for the flesh and the kernel. The development of the stone could also be included in such an hypothesis. In any event the fact must not be lost sight of that the differential development of flesh, stone, and kernel in varieties of the peach is governed by their genetic make-up.

Changes in Stone and Kernel

The data obtained in this investigation and the facts presented in the preceding discussion show that the ordinary conception of the three growth periods fails to express all of the growth activities of the fruit. Altho this concept is useful because it is easily understood and it does include fairly accurately the changes that occur in the size manifestation of growth, other growth phenomena should be considered.

Actually the three growth periods usually described by investigators explain primarily *only the size increase in the flesh*. The present study, together with previous work by the author, adds the following information concerning the development of the stone and the kernel:

The stone: *Period 1.* Increases rapidly in size to approximately a maximum, due to cell division and cell enlargement. Increase continues from bloom until stone is hard enough to cut away with a knife.

Period 2. Slow increase in size. Stone hardens rapidly and increases rapidly in dry matter. Little or no cell division takes place. Period continues until harvest in early varieties, but terminates before harvest in late varieties.

Period 3. In late varieties only. Stone is stationary or decreasing in size and in dry-matter content. Period continues until harvest.

The kernel: *Period 1.* Nucellus and integuments increase rapidly in size to nearly a maximum. No macroscopic evidence of endosperm or embryo. This period coincides with Period 1 of flesh and stone.

Period 2. Slow increase in size of nucellus and integuments. Endosperm and embryo are macroscopically evident; rate of size increase is usually correlated with lateness of ripening. Period continues until harvest in early varieties but ends with attainment of maximum embryo size in late varieties.

Period 3. In the late varieties only. Dry matter increases rapidly, particularly the ether extract.

The terms *early* and *late* as used here will apply to such varieties as Mayflower, Sneed, and Early Rose for early varieties and Elberta as a late variety. The intermediate varieties probably will, in general, exhibit the characters of the group they most closely approach in time of ripening. Exceptions may well be found as the number of varieties examined increases.

SUMMARY AND CONCLUSIONS

The seasonal development of the fruit on two six-year-old Hale-haven peach trees was observed from the time the trees were in full bloom to the time when the flesh became soft ripe. A vigor differential was established between the two trees by two 5-pound applications of nitrate of soda to one of them—the first, 17 days before full bloom, and the second just as the stones began to harden 51 days after bloom.

Samples were collected at weekly intervals and determinations were made of the diameter, volume, fresh weight, and dry weight of the entire fruit, the flesh, the stone, and the kernel. The flesh, stone, and kernel were analyzed for the content of the following constituents: reducing sugars, sucrose, starch and dextrin, hemicellulose, total nitrogen, ash, and ether extract.

When growth of fruit was measured by increase in its diameter, volume, or fresh weight, three periods of development were evident:

1. The first growth period, which ended when the stone was first hard enough to separate from the flesh—57 days after bloom. This period was characterized by rapid increase in size and fresh weight of flesh, stone, and kernel; by attainment of nearly maximum size of stone and kernel; by absence of macroscopic evidence of growth in endosperm and embryo until near the end of the period; and by an increase in the amount of each of the determined constituents.

2. The second growth period, which ended approximately 76 days after bloom. This period was characterized by a slow rate of increase in size of flesh, stone, and kernel; by a reduced rate of dry-matter accumulation in the flesh and kernel, but by the most rapid rate of increase in the stone; by the development of the endosperm and embryo to approximately maximum size; by a reduced rate of accumulation of all constituents in the flesh and the kernel, but by the most rapid increase in lignification and hemicellulose content in the stone.

3. The third growth period, extending to the soft ripe condition of the flesh 117 days after bloom in the check fruits and 123 days after bloom in the nitrated fruits. This period was characterized by an accelerating increase in size and dry matter of the flesh; by a decrease in volume and dry matter of the stone during the latter half of the period; by a decrease in volume but the most rapid increase in dry-matter of the kernel; by an increase in the amount of all determined constituents of the flesh, with a particularly rapid increase in sucrose during the last 11 days; by a decrease in the amount of all constituents of the stone; and by an increase in the amount of all constituents of the kernel except starch and dextrin, which decreased. Ninety-four percent of the total amount of ether extract in the kernel accumulated during the third period.

The transition from one period to the next was not abrupt; hence only approximate dates can be given for the duration of each period.

When dry-weight increase was used as the measure of growth, no clearly defined second period was evident, the rate of increase in each sampling interval being as great as that in the preceding interval. The rate of increase was accelerated, however, during the last three weeks before harvest.

The rate of development was almost parallel between the fruits of the two treatments, regardless of method of measurement, until about three weeks before harvest, when the check fruits developed more rapidly for a few days and then were surpassed by the fertilized fruits.

The principal effects of the nitrogen fertilization were:

In the tree: greater yield, more and longer shoots; larger, heavier and greener leaves; and more fruit buds for the succeeding year.

In the fruit: greater size, six days later ripening, slightly less intense color, no detectable difference in quality, and a greater ratio of flesh to stone on both the fresh-weight and the dry-weight basis.

In the flesh: higher percentages of starch and dextrin, ash, and nitrogen; but lower percentages of reducing sugars and hemicellulose.

In the stone: greater size and weight, higher percentages of nitrogen, hemicellulose, starch and dextrin; but lower percentages of sugars and ash.

In the kernel: greater dry weight, and greater percentages of all constituents except reducing sugars.

The fertilizing of peach trees with liberal quantities of a readily available nitrogenous fertilizer would thus seem highly desirable under conditions similar to those of this investigation, resulting in more vigorous vegetative growth, the formation of more fruit buds, and a greater yield of larger fruit as attractive in color and as high in quality as that from trees not so fertilized.

The necessity for giving detailed attention to the separate parts of the fruit in any study of the physiological development of the peach as a whole is emphasized by the data, which reveal some of the growth relationships existing between the flesh, stone, and kernel. Still further separation of the fruit parts, such as that of the kernel into integuments, endosperm, and embryo, and the development of more precise methods of analysis are necessary in order to add to the existing knowledge of the details of the growth processes.

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